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U.S. Nuclear Attack Subs

In Action No. 29

Al Adcock

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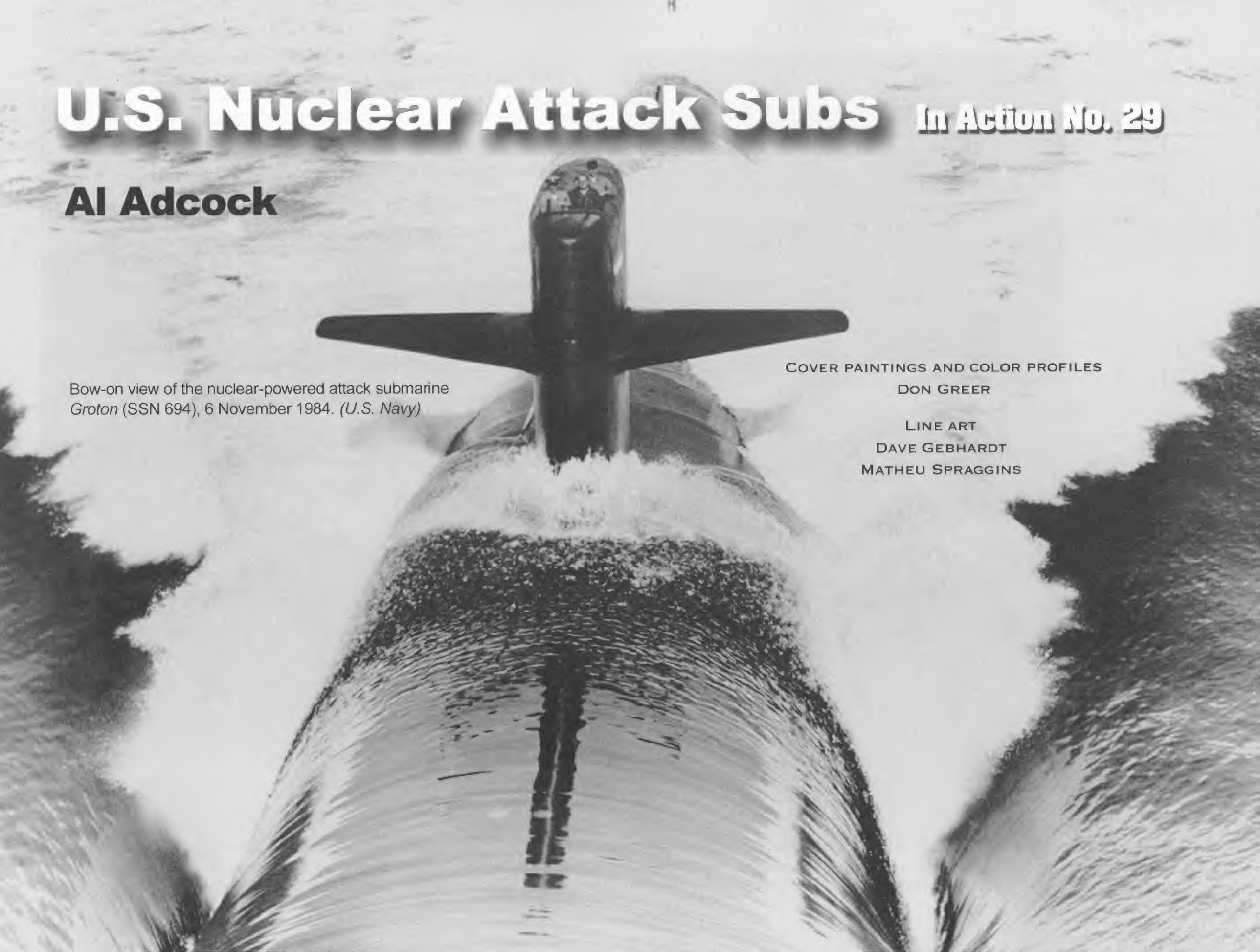

Bow-on view of the nuclear-powered attack submarine *Groton* (SSN 694), 6 November 1984. *(U.S. Navy)*

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MATHEU SPRAGGINS

Front Cover
USS Pittsburgh (SSN 720) launches a Tomahawk (UGM-109) Land Attack Missile (TLAM) toward a target in Iraq during the opening days of Operation Desert Storm in January 1991. *Pittsburgh* is a member of the *Los Angeles* class of nuclear-powered fast attack submarines.

Back Cover
Spadefish (SSN 668) sits near the North Pole during Atlantic Submarine Exercise Ice Exercise (LANTSUBICEX) 2-93 with the upper hull and sail protruding from the Arctic ice pack.

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Dedication

To Rear Adm. Arlington F. Campbell, U.S. Navy, (Retired), first captain (Gold Crew) of the fleet ballistic missile submarine *Ohio* (SSBN 726) and the second commander of the fast attack submarine *Richard B. Russell* (SSN 687).

Memphis (SSN 691) under way on the surface of the Atlantic Ocean on 14 November 1977. *Memphis* was the fourth boat in the *Los Angeles class* of U.S. Navy fast attack nuclear submarines. The pennant numbers on the sail are for publicity purposes only and will be removed before a sea patrol is undertaken. *(U.S. Navy)*

Introduction

Following the fall of the German Third Reich in May 1945, British and American naval engineers and shipbuilders were treated to the spoils of war. Perhaps the greatest finds were the discoveries of German Type XXI Undersea Boats (U-Boats).

History was repeating itself. Twenty-five years before, following the conclusion of World War I, "the war to end all wars," Allied forces discovered the advancements made by the Imperial German Navy in the field of submarines. These advancements enabled the U-Boats to rule the Atlantic (the same fate that befell the Allies at the beginning of World War II). The German U-81 Type displayed superiority in hull design, torpedoes, periscopes, and diesel-electric drive. These and other features would appear in U.S. Navy submarines in the "between the wars" period.

During World War II, the German Kreigsmarine (Navy) relied upon their Type VII and IX U-Boats, while the U.S. Navy utilized their *Gato*, *Tench*, and *Balao* classes to carry the fight to the enemy, mainly the Japanese Imperial Navy. The U.S. Navy operated very few submarines in the Atlantic and Mediterranean; instead, they relied on the British and U.S. hunter-killer forces (combined surface ships and aircraft) to fight the U-Boats.

By 1943, German U-Boat losses were exceeding production, and Admiral Dornitz, commander of German submarine forces, sought a better and faster submarine from the yards. Professor Doctor ING Helmuth Walther answered the plea and designed, with the aid of others, the Type XXI. The Type XXI utilized a streamlined hull and conning tower, plus the addition of a snorkel. The snorkel had been designed by a Dutch naval engineer and was discovered by the Germans when they conquered the "Low Countries," in 1940. The snorkel enabled the submarine to run submerged, operating on the diesel engines, while the batteries for the electric drive could be recharged. A total of 131 of the Type XXI had been completed by war's end, with very few seeing combat.

At the end of hostilities in Europe, the German fleet fell into the hands of all the Allies. Many of the U-Boats, though, had been scuttled to prevent them from falling into Allied hands. The Allies discovered the advancements made by the Germans in submarine design and production techniques. The Type XXI was probably the most important, as far as submarines were concerned, ranking with the V-2 rocket in terms of innovation. Designs that would not show up on U.S. Navy submarines until the 1950s were on the Type XXI.

While U.S. Naval investigators and designers from Electric Boat and others pored over the captured U-Boat designs, plans were put into place to improve existing U.S. submarines until the information and designs could be implemented on new U.S. submarines. The first attempts by the U.S. Navy to improve its submarines was the GUPPY I, II, and III programs.

GUPPY stood for Greater Underwater Propulsive Power. (The "Y" in the acronym was added to increase pronounceability.) Conversions, which began as early as 1946, applied only to the welded-hull *Tench* and *Balao* classes. A total of nine of the *Balao* and three of the *Tench* class were selected for the GUPPY I conversion program.

The conversions consisted of the removal of all deck guns and propeller guards. A streamlined bow was added, and a new cut-down and streamlined fairwater (sail, or in earlier terms, conning tower) replaced the old fleet boat type. A snorkel was added to enable the submarine to operate submerged and utilize the diesel to keep up with its intended prey. When the snorkel could not be used, a new, more powerful 126-cell battery became available and installed in the GUPPY Is. The installation resulted in the GUPPY I being cut in half, and the new batteries installed; this resulted in the GUPPY I becoming the GUPPY IA. When four of the 126-cell batteries were installed, the GUPPY I became GUPPY II.

Further modifications with engines, sonar, batteries, sails, and hulls resulted in GUPPY IA and GUPPY III. The GUPPY conversions featured two distinct types of sails. One was a streamlined structure, which replaced the stepped type. Both types of sails could be found in the 48 individual GUPPY-class submarines that had been modified between 1946 and 1952.

The first submarines built by the U.S. Navy following World War II were called submarine killers and used the designation SSK. The three submarines in the class were the

Barb (SS 220) was a typical *Gato* class of U.S. Navy fleet attack submarines utilized during World War II. *Barb* was powered by diesel engines on the surface and battery-powered electric motors while submerged. Barb sunk 17 Japanese ships while operating in the Pacific. *(National Archives)*

Cobbler (SS 344) was a World War II-era diesel-electric fleet attack submarine in the *Balao* class that had been modified to Greater Underwater Propulsion Power Program (GUPPY) II standards with a much-modified sail and bow configuration in the 1950s. The GUPPY conversions added a snorkel so the sub could cruise below the surface and draw in air for the diesel engine. *(U.S. Navy)*

leader *Barracuda* designated as SSK 1, followed by the *Bass* designated as SSK 2, and *Bonita* SSK 3 (later SS 550, SS 551, and SS 552). The "Killers" were short at 196 feet in length and featured a bulbous bow that housed, for the time, powerful sonar listening gear.

Developed in parallel with the GUPPY III program were the Fleet Snorkel alterations of 1950-1952. The Fleet snorkel program included the installation of snorkel and electronic upgrades on those *Balao* and *Tench* classes that did not receive the upgraded GUPPY alterations.

On 18 April 1949, the keel was laid for the *Tang* (SS 563), the first U.S. submarine built incorporating features that were found on the German Type XXI. The *Tang*-class subs were fast at 18 knots submerged, but the diesel power plants proved unreliable, and they were removed during overhauls in the late 1950s.

In 1950, Bureau of Ships and Construction (BuShips) authorized the construction of a radical new submarine design named the *Albacore* (AGSS 569). *Albacore* featured a hull design that was teardrop in shape. A single screw was fitted, and with 15,000 horsepower available speeds of up to 33 knots submerged were reported. *Albacore* was a "one-off" design used to develop future U.S. submarines.

The *Albacore* continued to influence U.S. submarine designs, and the *Barbel* (SS 580) class of diesel-electric submarines was built to the *Albacore* design. The three *Barbel* were the last diesel-electric submarines built for the U.S. Navy, and they would serve until 1990 as research and training submarines.

The future of submarines, though, was not only in the design of the hull, but also in power plant development that was begun just after World War II. A few of the German Type XVIIA and B U-Boats that fell into the hands of the Allies were powered by the Walther closed-cycle hydrogen peroxide-fueled engine. Tests by the U.S. Navy disclosed the unsuitability of the Walther system for use in submarines, but it could be adapted to torpedoes. The successful Mk 48 long-range torpedo utilized the closed-cycle type of power plant that used a piston engine and a hybrid hydrogen peroxide fuel.

In 1946, the U.S. Congress passed the Atomic Energy Act that established the Atomic Energy Commission (AEC), giving the AEC responsibility to develop atomic energy for a variety of uses. Capt. Hyman G. Rickover (USN) was assigned to the Bureau of Ships, and he recognized that atomic power could be harnessed and placed in ships, specifically submarines. In 1948 the AEC contracted with Westinghouse Electric to design, build, operate, and test a prototype pressurized water nuclear power plant. The Westinghouse Bettis Atomic Power Laboratory in Pittsburgh, Pennsylvania, began the development in 1950 of a nuclear power plant designated as S1W — the "S" standing for submarine, the "1" for first design, and the "W" for Westinghouse. When a General Electric reactor was fitted, a "G" was used. A "C" would indicate a Combustion engineering reactor. On 30 March 1953, the prototype reached criticality. The S1W would become the prototype for the Westinghouse S2W reactor that would be installed in the *Nautilus* (SS 571) in 1953, during her construction.

Fast attack submarines are supported while in base by submarine tenders (ASs). The sub tenders act like floating hotels and garages. They provide sleeping and eating facilities, spare parts, electronic support, and rearmament of torpedoes, decoys, and mines. Before the submarines begin a patrol, they are supplied with food and supplies necessary to sustain the crew for the duration of the deployment. The tenders also forward deploy to other forward areas of operations to support the attack submarines.

During World War II, U.S. submarines wore four schemes of camouflage colors. Measure 9, the Black System, and Measure 10, the Gray System, were applied to all submarines until Measures 32/3SS and 32/9SS were developed in late 1943. In 1953 a Measure SS-27F was authorized, and it was a development of Measure 32/3SS and 9SS. It was still being applied into the 1960s as the camouflage scheme appeared to have concealing abilities down to 100 feet, important when a submarine was operating in shallow waters. U.S. Navy submarines in the 21st century are painted or coated with a black material down to the red oxide anti-fouling coating. The *Seawolf* and *Virginia* classes appear to be painted or coated overall in an acoustic tile that was black in nature.

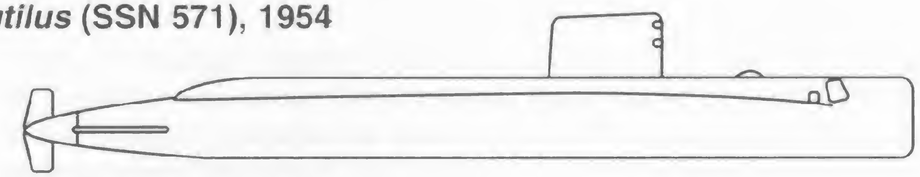
The submarine service has long been called the "silent service," not only because of submariners' reticence concerning their "boats," but also because today's U.S. Navy subs are so very quiet.

Albacore (AGSS 569) introduced the teardrop-shape hull, which enabled her to be the world's fastest submarine when she was commissioned. *Albacore* is configured in Phase I trim, which employed the cruciform stern planes. The hull shape was utilized on the *Skipjack* class of nuclear-powered submarines. *(Portsmouth Naval Shipyard)*

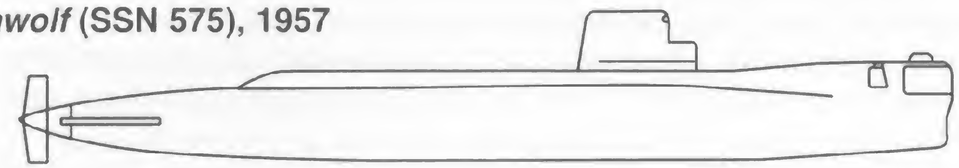
U.S. Navy submarine bases typically have a submarine tender, such as *Holland* (AS 32) that has the nuclear attack submarine *Finback* (SSN 670) moored alongside in The Holy Loch, Scotland. The submarine dry dock *Los Alamos* (AFDB 7) is in the background. The Holy Lock was closed as a sub base in 1991. *(U.S. Navy)*

Development of U.S. Nuclear Attack Subs *(Arranged Chronologically by Commissioning)*

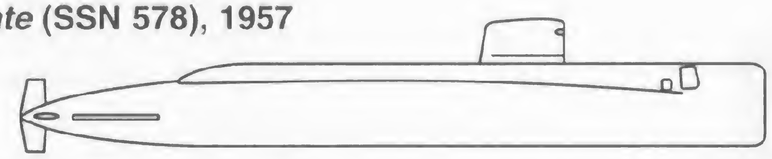
Nautilus **(SSN 571), 1954**



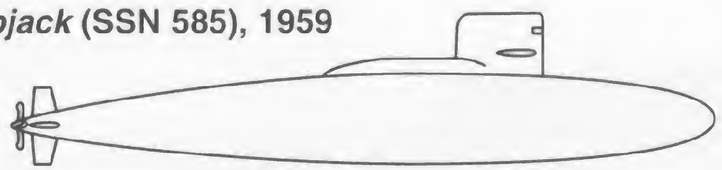
Seawolf **(SSN 575), 1957**



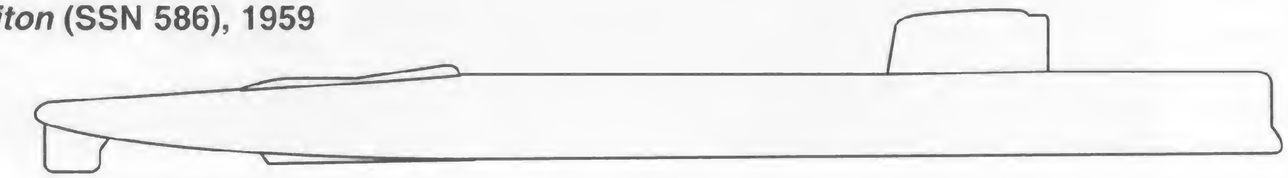
Skate **(SSN 578), 1957**



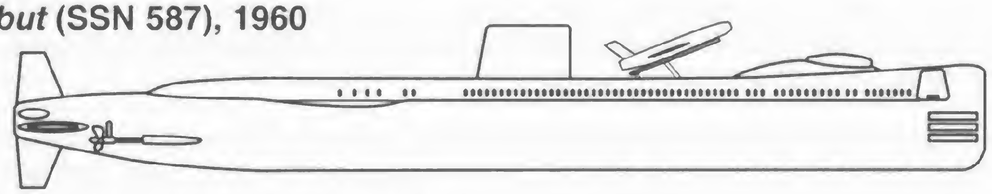
Skipjack **(SSN 585), 1959**



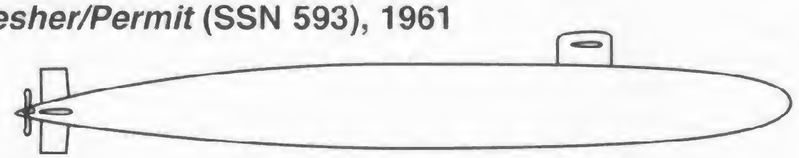
Triton **(SSN 586), 1959**



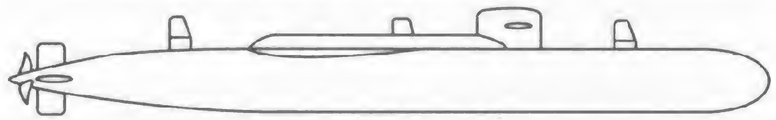
Halibut **(SSN 587), 1960**



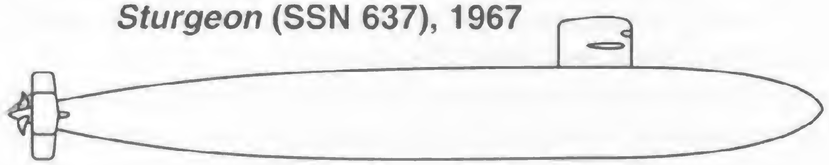
Thresher/Permit **(SSN 593), 1961**



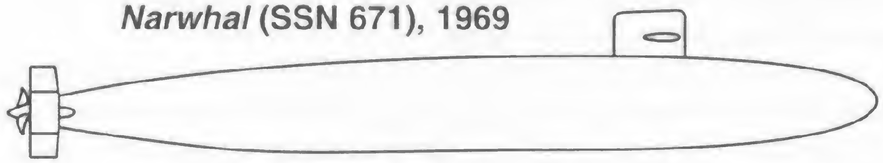
Tullibee **(SSN 597), 1960**



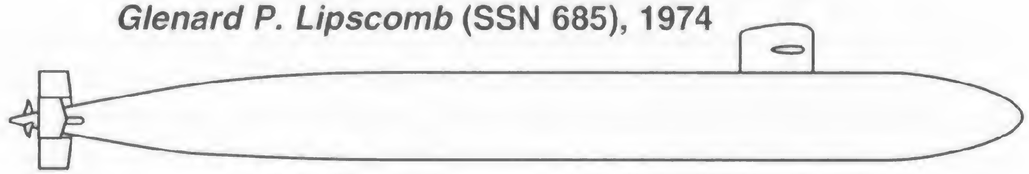
Sturgeon **(SSN 637), 1967**



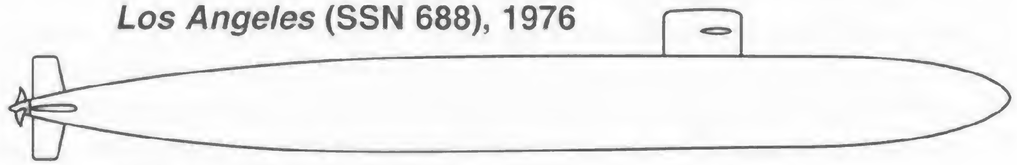
Narwhal **(SSN 671), 1969**



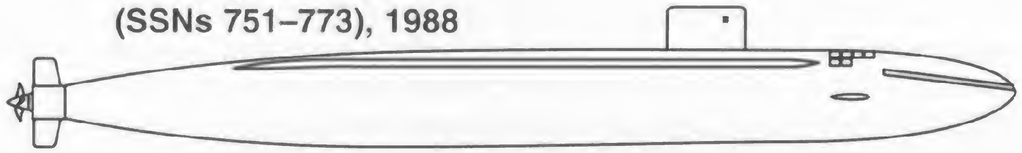
Glenard P. Lipscomb **(SSN 685), 1974**



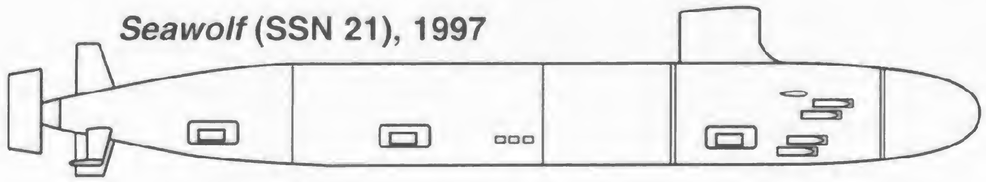
Los Angeles **(SSN 688), 1976**



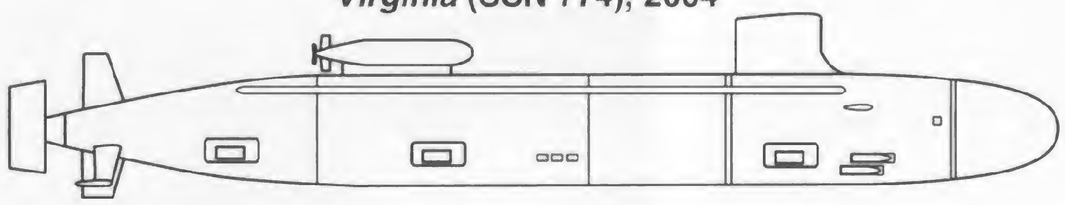
Los Angeles **Improved (SSNs 751–773), 1988**



Seawolf **(SSN 21), 1997**



Virginia **(SSN 774), 2004**



Nautilus

The submarine *Nautilus* (SSN 571) was authorized in 1952 to test the Westinghouse S2W reactor in a submarine. The driving force behind the experimental program was Capt. (later promoted to admiral) Hyman G. Rickover. Electric Boat, Groton, Connecticut, was chosen to construct the hull, and Westinghouse the reactor assembly and the steam turbines. The SCB-64 hull was a modified Tang/GUPPY type that was developed from information gathered from the German Type XXI and other captured records.

Nautilus was launched on 21 January 1954, and precommissioning trials began soon thereafter. Following eight months of upfitting and shakedown tests, *Nautilus* was commissioned on 30 September 1954. Following commissioning, *Nautilus* began a series of surface and underwater tests to demonstrate the extensive and new capabilities. On 11 May 1956, following three days of demonstrations to the U.S. Navy Board of Inspection and Survey, the submarine was accepted for unrestrictive service.

Nautilus had a complement of 105 — 13 officers and 92 enlisted. The submarine was constructed with five major compartments. From fore to aft they were: (1) the bow compartment that housed the torpedo room and forward crew berthing area; (2) the main quarters and galley compartment, divided into upper area, for "officer country," and lower area for galley and crew berthing; (3) the central operating compartment, divided into two sections comprising the fighting section and control section; (4) the reactor compartment and engine room; and (5) the most aft section, the stern section, that was divided into five spaces that comprised the after escape trunk, aft machinery space, after crew quarters, and storeroom. The stern compartment also housed a nucleonic laboratory that was used for various nuclear experiments concerning the health and welfare of the crew operating the first nuclear-powered ship.

Nautilus was 319.42 feet in length, with a 28-foot beam and a draft of 25.5 feet. Displacement was rated at 3,764 tons surfaced and 4,040 tons submerged. Power for the twin screws was provided by a 15,000 shaft horsepower (SHP) Westinghouse S2W, formerly designated as STR Mk II, pressurized water-cooled reactors that drove a pair of Westinghouse geared steam turbines. An auxiliary diesel standby power plant and snorkel were installed in the event of a reactor failure. *Nautilus* was credited with a surface speed of 20 knots and a submerged speed of 25 knots. Diving depth was limited to 500 feet.

Nautilus was fitted with six bow-mounted torpedo tubes; no stern tubes were installed due to space constraints. A total of 18 torpedoes could be carried in the torpedo room. In addition to torpedoes, a variety of mines and decoys could also be deployed. Torpedo control was by the Mk 101 Mod. 6 Fire Control System.

She achieved many firsts in her career. Besides being the first nuclear-powered ship, *Nautilus* was the first to travel under the polar ice pack at the North Pole.

Nautilus can be visited at the Nautilus Memorial Submarine Force Library and Museum located on base at Groton, Connecticut.

Nautilus (SSN 571) was the first ship powered by nuclear power. She launched on 21 January 1954 from Electric Boat, Groton, Connecticut. On 17 January 1955, Cmdr. Eugene P. Wilkinson signaled Submarine Force Commander the message, "Underway on nuclear power." Deployed in the Atlantic, *Nautilus* was carrying a modified World War II camouflage of SS-27F, a Black (BK) and Ocean Gray (5-O) scheme. *(Electric Boat)*

Nautilus operating out of Groton, Connecticut, painted in an overall scheme of Black #82. A pair of wire whip antennas and a navigation periscope antenna are located on the sail area. Her name has been painted on the aft hull superstructure. A deck crewman is working on the forward upper hull area. The hull numbers would have been removed before a patrol was initiated. *(U.S. Navy)*

Seawolf

The *Seawolf* (SSN 575) was the world's second nuclear submarine and the only U.S. submarine built with a liquid sodium-cooled nuclear reactor. She was a sister to the *Nautilus*, utilizing submarine design SCB-64A, a GUPPY-type hull, but with a stepped sail.

Constructed by Electric Boat, Groton, Connecticut, *Seawolf* was launched on 21 July 1955. She was constructed to test the General Electric S2G Submarine Intermediate Reactor (SIR) that utilized liquid sodium as the cooling agent. The liquid sodium-cooled reactor was smaller and lighter and produced the same horsepower as the S2W Westinghouse reactor.

Seawolf was commissioned on 30 March 1957 and entered trials that would lead to her being accepted into U.S. Navy Fleet service. Following sea trials in which *Seawolf* demonstrated her abilities in NATO exercises, it was decided to remove the S2G reactor and replace it with the Westinghouse S2Wa water-cooled reactor, although the General Electric geared turbines were retained. The conversion took over three years to complete.

Seawolf was 337.5 feet in length, had a beam of 27.67 feet and a draft of 23 feet. Displacement was rated at 3,765 tons surfaced and 4,399 tons submerged. The hull utilized the Electric Boat EB 253 A design that was a modified GUPPY type, which featured an upturned bow protrusion that contained the sonar suite. *Seawolf* was fitted with six bow-mounted torpedo tubes and no stern tubes. Surface and submerged speeds were rated at 20-plus knots, and maximum diving depth was limited to 500 feet.

Designed from the onset to serve in the anti-submarine warfare (ASW) role, the *Seawolf* was used mainly as a test bed vehicle, as newer submarines such as the *Skipjack* class were proving to be more suited to the ASW role.

In 1969 *Seawolf* was designated as an Auxiliary Submarine Transport (APSS) and used on clandestine operations. Following that assignment, *Seawolf* was transferred to the Pacific Fleet where she served with Submarine Development Group One (SDG-1) Vallejo, California, until decommissioning on 31 March 1987, having served with the U.S. Navy for 30 years.

Seawolf (SSN 575) surfaces on 6 October 1958, after 60 continuous days under the sea. A General Electric (GE) Mark II liquid metal (sodium) cooled reactor originally powered the *Seawolf*. After two years of operation, the GE reactor was replaced by a Westinghouse S2W pressurized water-cooled reactor. *Seawolf* is camouflaged in Measure SS-27F. *(U.S. Navy)*

Seawolf operates in the San Francisco Bay in 1977. The hull and fairwater (sail) are from a GUPPY design introduced in the 1950s. *Seawolf* was converted to an auxiliary submarine transport and used for clandestine operations in the Pacific recovering Soviet missile parts and tapping underwater telephone cables. *(U.S. Navy)*

Skate Class

The *Skate* class was comprised of four boats: *Skate* (SSN 578), *Swordfish* (SSN 579), *Sargo* (SSN 583), and *Seadragon* (SSN 584). All used the SCB-121 submarine design that was a modified GUPPY-style hull and streamlined sail, as in the *Nautilus*.

Electric Boat constructed *Skate*, Portsmouth Naval Shipyard *Swordfish* and *Seadragon*, while Mare Island Naval Shipyard constructed *Sargo*.

The lead boat, *Skate*, was launched on 16 May 1957 and commissioned seven months later following sea trials. All members of the *Skate* class had been commissioned by 1959. The Westinghouse S3W pressurized water-cooled reactor powered the *Skate* and *Swordfish*, while the Westinghouse S4W reactor powered the *Sargo* and *Seadragon*. Both reactors provided 6,600 shaft horsepower through the Westinghouse geared steam turbines. The *Sargo* had originally been authorized as a diesel-electric powered submarine but was changed to nuclear power in 1955.

All of the *Skate* class were 267.7 feet in length, had a beam of 25 feet and a draft of 22 feet. Displacement varied, with the 578 boat displacing 2,360 tons on the surface, 579 boat 2,550 tons surface, and the 583 and 584 boats 2,547 tons surface. The variations came about by the installed reactors. Rated speeds were the standard 20-plus knots surface, with a diving depth of over 400 feet.

The *Skate* class was equipped with six bow-mounted 21-inch torpedo tubes and two short tubes in the stern. The twin-screw arrangement and smaller reactor allowed for enough room in the aft crew quarters to fit the two tubes and spare torpedoes. For fire control, the Mk 101 Mod 19 torpedo fire control system was fitted, and the BQS-4 sonar array system was located in the bow.

The *Skate* class was designed from the outset as attack submarines to protect U.S. carrier fleets and to keep the shipping lanes open. The hull design was similar to the *Nautilus* design, only smaller. The GUPPY III hull had a rounded bow and a streamlined and strengthened sail to enable the *Skate* class to break through the polar ice layer. This feat was demonstrated on 17 March 1959 when the *Skate* surfaced at the North Pole, marking the first time any submarine had surfaced at geographic north.

On 2 June 1989, the *Seadragon* was decommissioned, the last of the *Skate* class to be in service. The *Skate* class demonstrated its ability for over 30 years, pioneering and exploring the feasibility of nuclear power installed in multiple submarines of the same design.

Skate (SSN 578) was the lead boat in a class of four. *Skate* surfaced at the North Pole on 17 March 1959, becoming the first U.S. Navy sub to break the surface. The bow-mounted forward torpedo doors are framed by a coating of ice. The bow-mounted forward diving planes are retracted into the hull. *(U.S. Navy)*

Swordfish (SSN 579), the second ship in the *Skate* class, became the first nuclear-powered submarine to operate in the Southwest Pacific Area of Operations. A Westinghouse S4W pressurized water-cooled reactor powered the *Swordfish*. The sea watch and other crew have manned lookout positions atop the fairwater. *(U.S. Navy)*

Sargo (SSN 583) surfaces through the ice on 9 February 1960 at the North Pole area, with only the fairwater penetrating. Access to the fairwater was through the use of a Jacob's ladder, as seen here being used by one of the crewmembers. With the advent of nuclear power, U.S. subs could roam freely under the Arctic ice pack. *(U.S. Navy)*

Sargo became the third U.S. submarine to surface at the North Pole, surfacing there 9 February 1960 after cruising under the Arctic ice pack. *Sargo* surfaced through the ice seven times en route to the Pole. A whip antenna and a retractable antenna have been extended to communicate with Commander Submarines Atlantic (COMSUBLANT). *(U.S. Navy)*

Seadragon (SSN 584) passes the Ram Island Ledge Light, Casco Bay, Maine, at the entrance to Portland Harbor in March 1958 during builder's trials out of Portsmouth Naval Shipyard, Kittery, Maine. The *Skate* class featured a *Nautilus*-type hull and fairwater with modified bow planes that enabled the sub to penetrate the ice at the North Pole. *(U.S. Navy)*

Skipjack Class

The *Skipjack* class brought a number of firsts to the U.S. submarine forces. They were the first U.S. nuclear submarines to be powered by a single screw, and the first U.S. production submarine with a single hull and sail-mounted diving planes.

The lead boat *Skipjack* (SSN 585) was laid down at Electric Boat on 29 May 1956. The Electric Boat EB-269A design resembled the *Albacore* (AGSS 569) type teardrop-shape hull. All of the *Skipjack* class were powered by the S5W Westinghouse pressurized water-cooled reactor that produced 15,000 shaft horsepower and drove a pair of steam turbines that were connected by a shaft to the single five-blade propeller. This single propeller design enabled the *Skipjack* class to be the fastest submarines in the fleet, far exceeding 30-plus knots in submerged speed.

The *Skipjack* class was provided with many redundant systems. There were two heat exchangers, two pressurized water coolers, and twin turbo generators, as well as a pair of small diesel power plants for emergency power. All of the *Skipjack* class were 251.9 feet in length, 31.6 feet in beam, and 28 feet in draft. Displacement was rated at 3,075 tons on the surface and 3,513 tons submerged. Official U.S. Navy performance figures were the usual rated 20 knots surface speed and 400 feet diving depth.

The *Skipjack*-class subs were equipped with six bow-mounted Mk 59 torpedo tubes, and no stern tubes were fitted. The Mk 14/16 anti-ship and Mk 37 ASW torpedoes could be carried along with the high-speed Mk 48 torpedo. The Mk 45 ASTOR was carried for a short period of time. The ASTOR was a nuclear-tipped wire-guided torpedo designed to eliminate concentrated enemy fleets. For torpedo control, the Mod 17 version of the Mk 101 system was fitted. The BQR-4 active/passive sonar system, which included the BQR-23 passive array, was located in the bow.

There were six submarines in the *Skipjack* class, built by four shipyards. Electric Boat constructed the lead boat *Skipjack* (SSN 585) and the *Scorpion* (SSN 589), Mare Island Naval Shipyard built the *Scamp* (SSN 588), Ingalls Shipbuilding built the *Sculpin* (SSN 590) and *Snook* (SSN 592), and the *Shark* (SSN 591) was constructed by Newport News Shipbuilding and Drydock. The *Scorpion* was laid down twice. The first keel was cut in half, and a 130-foot missile tube section was inserted. *Scorpion* was renamed the *George Washington* (SSBN 598) and armed with 16 Polaris A-1 ballistic missiles. The second *Scorpion* was laid down, and, upon completion and commissioning, she joined Submarine Squadron Two, Groton, Connecticut.

Tragically, *Scorpion* was lost on 21 May 1968 while operating off the Azores, with the loss of all hands. No cause of the accident has ever been determined, but it has been speculated that either a torpedo malfunctioned in the tube, or a torpedo fired in a test returned and hit the submarine.

Both *Scamp* and *Sculpin* saw service during the Vietnam War while serving in the Pacific area. They received Battle Stars for their flags. All of the *Skipjack* class served as the most modern submarines, with speed, maneuverability, and deep diving capabilities that no other submarine of their time possessed.

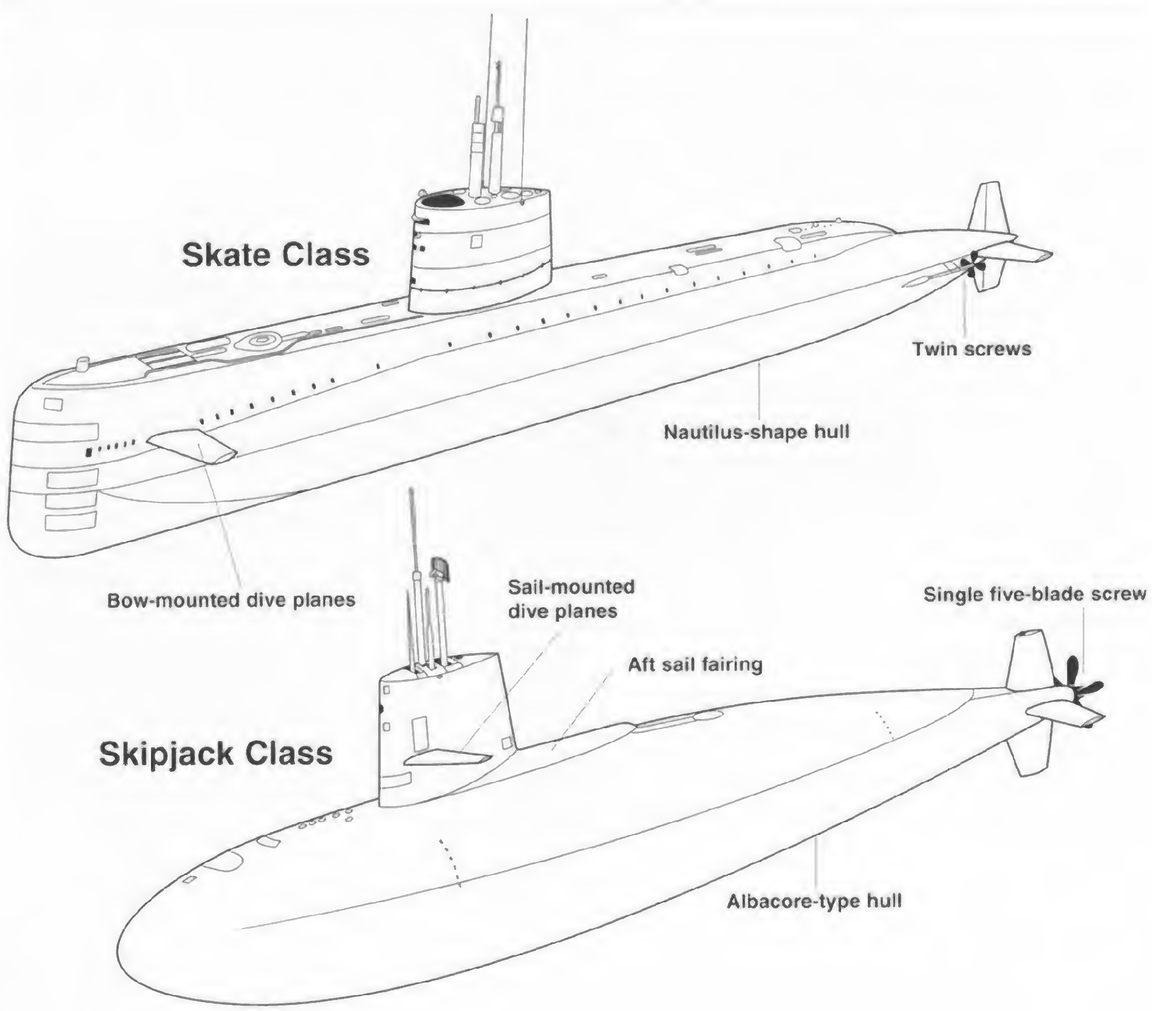
Skipjack (SSN 585) was the first U.S. nuclear submarine to employ the teardrop-shape hull that was pioneered by the *Albacore*. With the new hull shape and the 15,000-shaft horsepower nuclear reactor, the *Skipjack*-class subs were the speediest U.S. fast attack submarines. The dive planes have been moved to the fairwater, and a streamlined fairing has been added to the sail to house additional hydrophones. *(Electric Boat)*

Skipjack, on builder's trials out of Electric Boat, Groton, Connecticut, in 1959. The *Skipjack* was commissioned on 15 April 1959, and she served for over 30 years before being decommissioned on 19 April 1990. *Skipjack* last served with Submarine Squadron Two (SUBRON 2) Groton, Connecticut. *(Elsilrac)*

Temporary guardrails have been erected on the fairwater planes as *Scamp* (SSN 588) undergoes builder's trials out of Mare Island Naval Shipyard, California, in 1961. *Scamp* would go on to serve in the Pacific and earn three Battle Stars for service during the Vietnam War. The sub's name has been painted on the fairwater streamlined extension. *(U.S. Navy)*

Scamp moves at high speed, riding very low in the water with just the fairwater exposed. *Scamp* and her sisters were fitted with six bow-mounted torpedo tubes and were the first U.S. submarines to have a centralized attack center. *Scamp* was decommissioned on 28 April 1988, after 27 years of service. *(U.S. Navy)*

Hull Shape Development



Scamp arrives at Roosevelt Roads, Puerto Rico, in the fall of 1985, for a port call and to do some training in the joint U.S./South American Exercise UNITAS XXV. The *Skipjack* class featured a single hull design that increased interior space and reduced displacement. A navigation periscope and radio mast are extended out of the fairwater. *(U.S. Navy)*

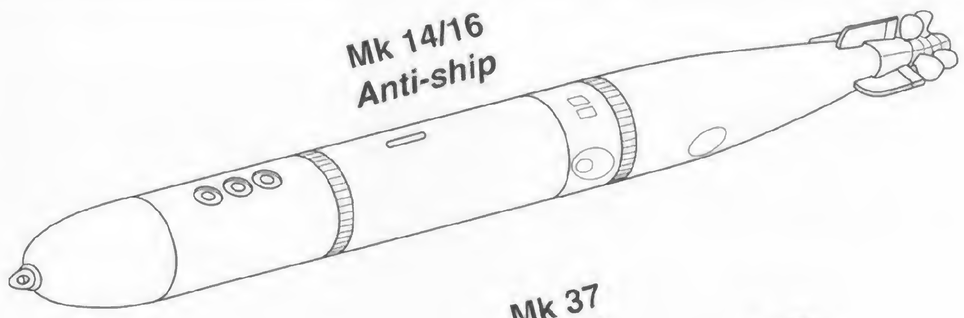
The deck crew of *Scorpion* (SSN 589) makes preparations to come alongside the Aviation Support Ship *Tallahatchie County* (AVB 2) outside Claywall Harbor, Naples, Italy, on 10 April 1968. The trailing wire antenna is still extended from the fairwater, and the temporary windshield has been erected for the sea watch. The hull number and name have been over-painted Black to protect the identity of the sub. *(Elsilrac)*

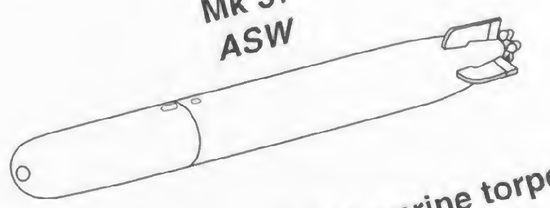
Scorpion, sister ship of the *Skipjack*, returns to her berth at General Dynamics Corp.'s Electric Boat shipyard, Groton, Connecticut, after two days of successful builder's trials in the Atlantic in June 1960. On board were Vice Adm. Hyman G. Rickover, seen on the port side dive plane, with the sub's captain, Cmdr. Norman B. Bessac, with hands on hips. *Scorpion* was lost in early May 1968, perhaps by a malfunctioning/errant Mk 37 homing torpedo. *(U.S. Navy)*

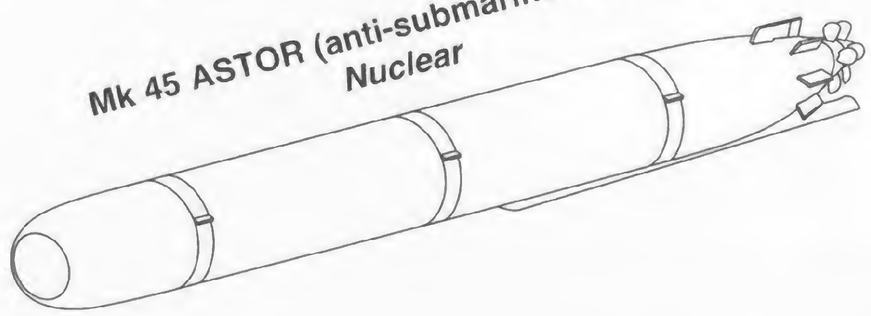
(Left) Sculpin (SSN 590) under way on the surface in May 1961 on builder's trials in the Gulf of Mexico. *Sculpin* was constructed by Ingalls Shipbuilding, Pascagoula, Mississippi, and named for the highly decorated World War II fleet submarine *Sculpin* (SS 191) that was sunk by Japanese naval gunfire in 1943. *(U.S. Navy)*

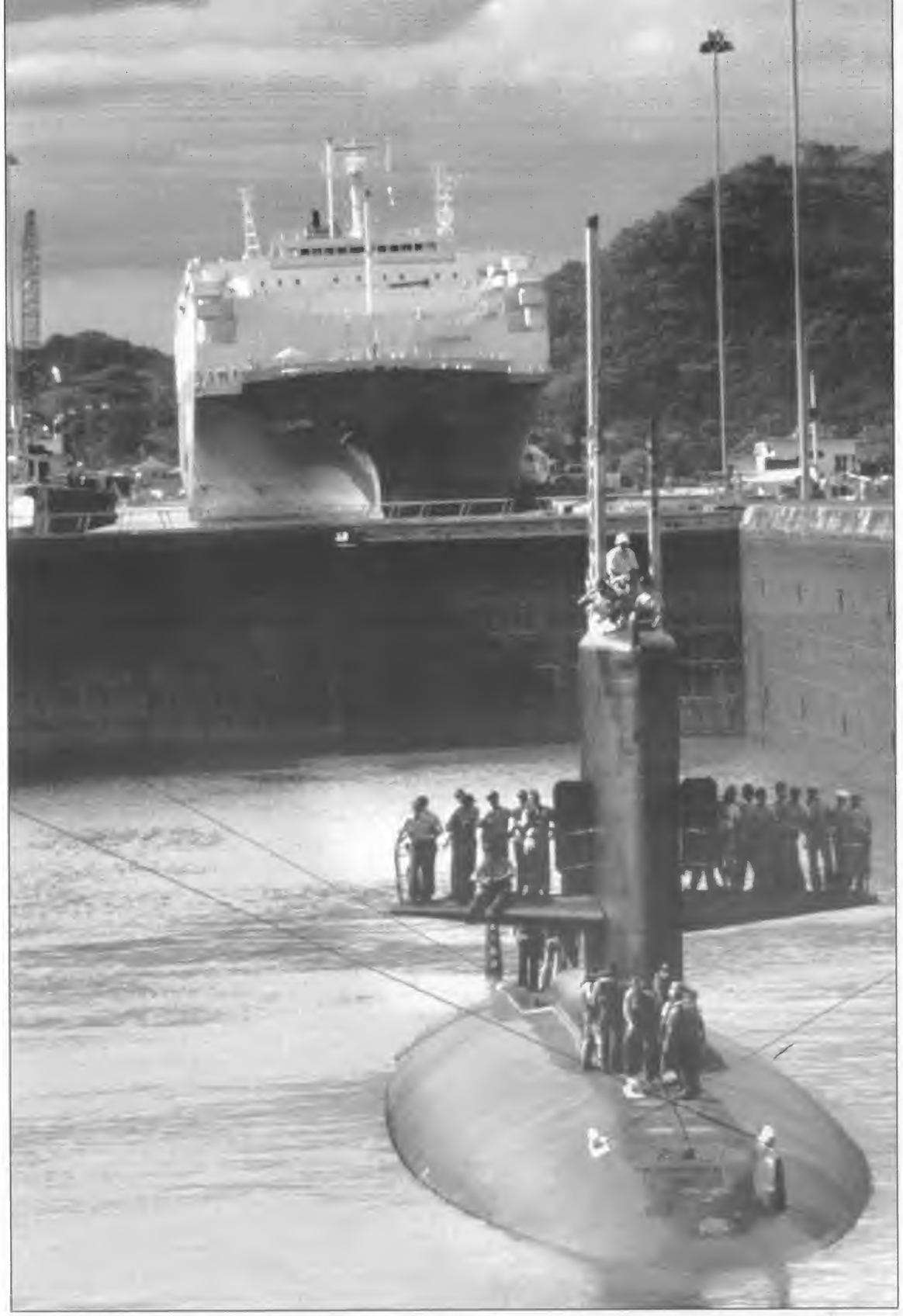
(Below) Shark (SSN 591) on trials out of Newport News Shipbuilding, Virginia, in 1961. *Shark* and many other U.S. early fast attack nuclear submarines were named to honor submarines lost during World War II in the Pacific. The men on sea watch are manning the fairwater, and the sub's sea search radar antenna is extended up. *(Elsilrac)*

Torpedoes









Shark making transit through the Mira Flores Locks, Panama Canal, on 11 November 1989. An automobile transport ship awaits its turn to enter the locks to be lowered to the next level. *Shark* was making the eight-hour, 51-mile journey from the Atlantic to the Pacific. Temporary chocks have been placed on the superstructure to attach tow cables to the sub. *(U.S. Navy)*

With Sugar Loaf Mountain in the background, *Snook* (SSN 592) prepares to enter the harbor at Rio de Janeiro, Brazil, in 1984 to participate in joint U.S./South American Exercise UNITAS XXV. The protrusions on the forward and rear superstructure areas are domes for hydrophones. The towed array is still extended out of the housing that is adjacent to the fairwater extension. The majority of the masts and periscopes have been extended. The masts are camouflaged in a scheme of Dark and Light Gray. (*U.S. Navy)*

Shark on trials in the Atlantic out of Newport News, Virginia, 31 January 1961. The rudder has a painted warning message concerning underwater projections. Sea search radar, communication, and periscope masts are extended while she operates on the surface. *Shark* served SUBRON 2 until she was decommissioned in 1990. *(U.S. Navy)*

Triton

In 1952 the U.S. Navy was authorized the funds to build two radar picket submarines (SSRNs), the *Sailfish* (572) and *Salmon* (573). They were to be used to warn U.S. carrier fleets utilizing large radar antenna mounted on their decks. By using their sonar array and radar, all threats could be located and the threat information passed to the fleet. Soon after the *Sailfish* and *Salmon* were launched, the keel for the *Triton* (SSRN 586) was laid down at Electric Boat on 19 August 1958.

Triton was the longest U.S. submarine ever built, and she held that title until the fleet ballistic missile submarine *Ohio* (SSBN 726) was launched in 1979, 21 years later. *Triton*'s hull was 447 feet in length, with a beam of 37 feet and a draft of 24 feet. Displacement was rated at 5,940 tons surfaced and 7,773 tons submerged. The large radar antenna was housed in the sail and could be raised and lowered hydraulically out of the sail for use.

On 10 November 1959, *Triton* was commissioned with Capt. Edward L. Beach in command. Beach was the well-known author of the World War II book, "Run Silent Run Deep." Soon after commissioning and sea trials, he took the *Triton* on a circumnavigation of the earth. The trip was made submerged and it covered 41,500 miles in 60 days and 21 hours in 1960, at an average speed of 15 knots. *Triton* was forced to surface off the Falkland Islands to allow a U.S. Navy helicopter to airlift a seriously ill crewman for hospital care.

Triton was the only U.S. submarine to be equipped with two General Electric S4G nuclear reactors, which together produced 34,000 horsepower that powered the two General Electric geared steam turbines that in turn drove the two propellers. The hull was an Electric Boat 260 A design, a modified GUPPY type. In a departure from normal designs, no vertical rudder was fitted.

The *Triton* was fitted with six Mk 60 torpedo tubes, four in the bow and two in the stern. A Mk 101 Mod 11 torpedo fire control system was utilized in conjunction with the bow-mounted BQS-4 sonar suite. The crew complement was 170, 14 officers and 156 enlisted. In 1961, when the radar picket concept was abandoned, *Triton* was reclassified as an SSN, and in 1962 the radar antenna and associated equipment were removed. She returned to service in 1964.

Now considered as second line, she was relegated to testing duties. The spaces that were devoted to the extendable radar antenna and other areas taken up by electronic equipment were used to test new equipment. Plans had been proposed to convert the *Triton* into an Underwater National Command Post, but no funds became available.

She was decommissioned on 3 May 1969 and delivered to Bangor, Washington, for storage and reactor removal.

Triton (SSN 586) under way in 1958. She was originally classified as a radar picket submarine (SSRN) and fitted with a large radar antenna that retracted into the center of the sail area. The *Triton* was designed to travel on the surface with a carrier battle group, warning of any air or sea threats. *Triton* was the largest U.S. submarine until the *Ohio* class of fleet ballistic missile submarines was constructed. *(Electric Boat)*

Triton was the only U.S. submarine to be constructed with two nuclear reactors. *Triton* circumnavigated the earth in 60 days and 21 hours in 1960, completely submerged, traveling over 41,500 miles, only surfacing off the Falkland Islands so an ill crewman could be removed by helicopter. The opening for the retractable radar antenna is the modified "T" shape atop the sail. *(U.S. Navy)*

Halibut

The *Halibut* was laid down on 11 April 1957 at Mare Island Naval Shipyard as SSGN 587, the "G" standing for Guided Missile. The *Halibut* was the first submarine built specifically to carry and launch guided missiles.

Halibut was 350 feet in length, with a beam of 29.53 feet and 21.42 feet in draft. Displacement was rated at 3,915 tons surfaced and 4,895 tons submerged. Originally to be diesel/electric powered, a single Westinghouse S3W nuclear reactor that provided 6,000 horsepower was installed, and it drove the twin-geared turbines that were connected to the twin screws. Six torpedo tubes were fitted, four in the bow and a pair in the stern. Mk 101 Mod 11 torpedo fire control was in conjunction with the BQR-4 sonar suite.

The *Halibut* was designed and constructed to carry and launch the Chance Vought Regulus guided missile. The SSM-N-8A Regulus I missile system was housed in a hangar in the area between the set-back sail and the bow. The missile hangar could carry five of the Regulus missiles, four in storage and one on the launcher. To launch the missile, it was necessary for the *Halibut* to come to the surface, the hangar door raised, and the missile rolled out. To get the missile airborne, a pair of Rocket Assisted Take Off (RATO) bottles were attached. The Regulus I had a range of over 400 miles, and it could be equipped with either a W-5 or W-27 fusion warhead. The missile was guided to its target by radio control.

The *Halibut* was also equipped to handle a pair of advanced Regulus II supersonic missile systems, but that project was cancelled in favor of the Polaris ballistic missile system that was being fitted to the *George Washington* class of fleet ballistic missile submarines that were being built. Following the cancellation of the Regulus program, the *Halibut* entered Mare Island for conversion to an SSN.

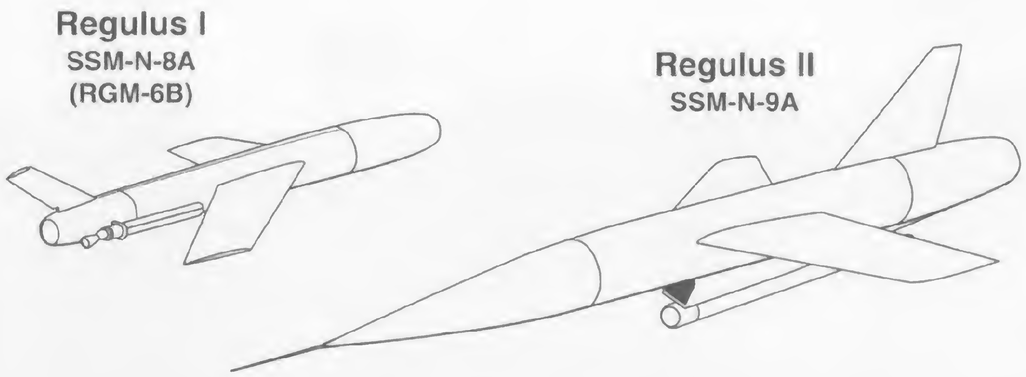
The conversion included removal of all missile-handling equipment. The conversion also included installation of a ducted bow thruster mounted on the roof of the hangar door for precise maneuvering, a large and powerful (for the time) Univac computer, bunks, and a trunk to allow embarked SEAL teams to leave and enter the submarine. A pressure/decompression chamber, which resembled the Deep Submergence Rescue Vehicle (DSRV) was installed on the aft hull superstructure. In order to hide the actual identity of the chamber, the U.S. Navy painted the name Mystic and DSRV-1 on the side to complete the ruse. The *Halibut* then was used in covert actions and used to tap into telephone lines operated by the Soviet Union as well as recover missile parts that fell into the Pacific Ocean following Soviet tests. She also was able to locate Soviet *Golf*-class submarine that had sunk in the Pacific Ocean.

When the *Halibut* was decommissioned on 30 June 1976, she was the most highly decorated U.S. submarine during the Cold War period, earning one Presidential Unit Citation and three Navy Unit Citations for service to her country. The *Parche* (SSN 683) replaced her in her highly secretive work.

Halibut (SSGN 587) prepares to launch an LTV Regulus I missile on 31 March 1960. With this launching, the *Halibut* became the first nuclear-powered submarine to launch a missile. Regulus was fitted to carry a W-5 fission warhead, and the missile had a range of 575 miles. Up to five missiles were stored in the hangar area midway between the bow and set-back sail area. *(U.S. Navy)*

In company with the carrier *Lexington* (CV-16), the *Halibut* launches a Regulus I missile in 1961 during a Southeast Asia Treaty Organization (SEATO) exercise. The *Halibut* was originally constructed to handle the improved SSM-N-9 Regulus II missile, but in 1958 the project was cancelled in favor of the Polaris Submarine Launched Ballistic Missile (SLBM) program. The Regulus used a pair of Rocket Assisted Take Off (RATO) bottles to take off. *(Submarine Forces Library)*

Regulus Cruise Missile



Halibut as fitted with the vector/thruster on the former hangar deck. The hangar area, known as the "bat cave," was used by SEAL teams and members of an operations team that were able to tap into Soviet underwater telephone lines off the Pacific Coast area. *Halibut* is camouflaged in a Measure SS-27F scheme. When operating covertly, the sub's hull number would be painted out on the sail. *(U.S. Navy)*

When the Regulus program was cancelled, the *Halibut* was converted to a covert operation submarine and redesignated as SSN 587. All of the missile-handling components were removed, and a giant Univac computer was installed in the hangar area along with 16 bunks. The conversions also included the installation of a ducted vector/thruster mounted atop the hangar area for precise maneuvering and a raised sail to handle additional electronic equipment. *(U.S. Navy)*

Halibut departs San Francisco Bay on 4 June 1960 with what appears to be the DSRV-1 Mystic embarked on the aft deck. The "DSRV" was in fact a pressure/decompression chamber used by divers while on deep-dive clandestine missions off the coast of the Soviet Union. *Halibut* was also able to locate the sunken Soviet ballistic missile submarine, the *Golf II*, K-129, in 14,000 feet of water in the Pacific. *(National Archives)*

Tullibee

When the U.S. Navy began design studies for a small, lightweight, highly maneuverable submarine, it envisioned a whole class of inexpensive nuclear attack subs to protect shipping lanes and carrier battle groups. As designed, the small submarines were to have been of the 1,000-ton class and have a sustained speed of 30 knots submerged.

The first of the envisioned class was laid down at Electric Boat on 26 May 1958 and named the *Tullibee* (SSN 597). *Tullibee* was named to honor the *Gato*-class *Tullibee* (SS 284) that was sunk during World War II by its own malfunctioning torpedo. The *Tullibee* was originally classified as a sub killer and designated as SSKN 597, but changed to SSN in 1959.

The *Tullibee* was built using Electric Boat EB-270A submarine design that was a departure from conventional submarine design. Originally designed for a 1,000-ton displacement submerged, the displacement grew to 2,640 tons submerged and 2,317 tons on the surface. The hull utilized the *Albacore* teardrop design, with a large extension aft of the sail. The main reason for the dramatic increase in displacement was the additional size required by the experimental Combustion Engineering S2C pressurized nuclear reactor.

The *Tullibee*, after the fitting of the reactor, was 273 feet in overall length, and 23.3 feet at the beam with a draft of 21 feet. The Combustion Engineering reactor drove two Westinghouse turboelectric drives that supplied power to a single five-blade propeller. The turboelectric drives were chosen because they made less noise than the steam turbines. The hull shape and single propeller gave the *Tullibee* a speed of well over the stated 20 knots submerged. Diving depth was rated at 400 feet.

The *Tullibee* was the first U.S. submarine to have the whole bow area dedicated to the sonar suite, the four torpedo tubes having been moved to amidships and angled out 10 degrees from the centerline. The bow sonar was the Raytheon BQQ-2 system that consisted of the BQS-6 active and BQR-7 passive conformal array. The *Tullibee* was further fitted with the BQG-4 Passive Underwater Fire Control Feasibility System (PUFFS). Originally fitted with two PUFFS domes, one located on the forward upper hull and one on the aft hull, the domes were a prominent feature of the *Tullibee*. Later, three domes were fitted; the third one was located on the large sail extension. The PUFFS system had earlier been tested on the GUPPY-modified *Balao* and *Tench* classes.

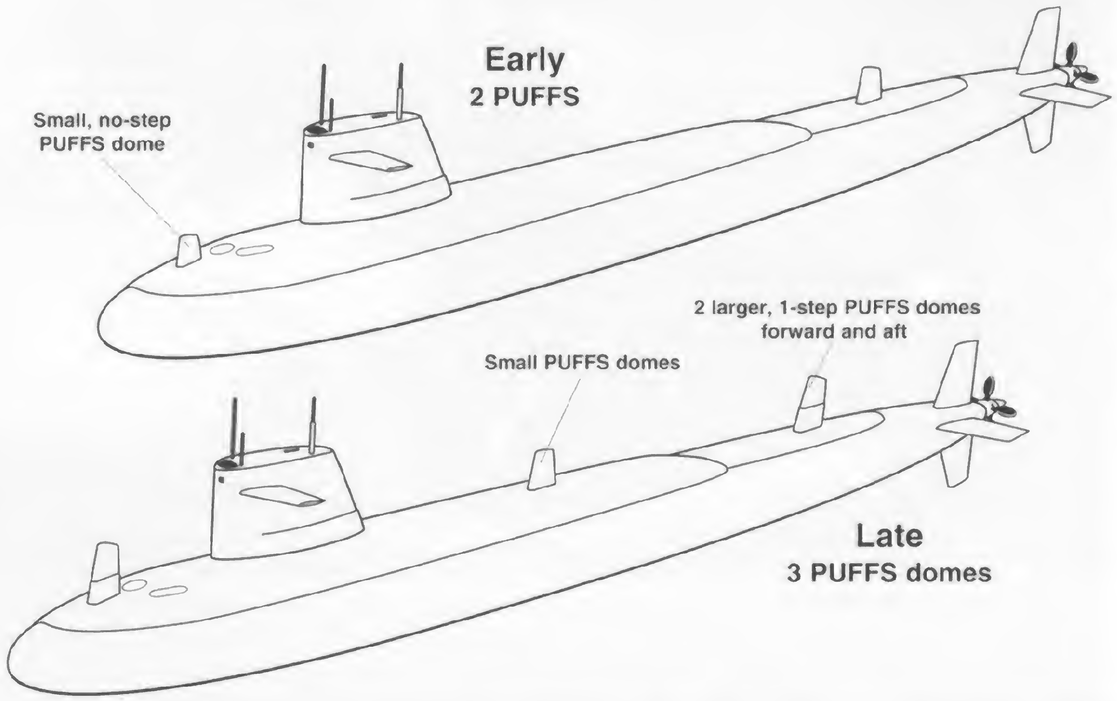
When the *Tullibee* first entered service, she was assigned to Submarine Squadron Two (SUBRON 2) at Naval Submarine Base, Groton, Connecticut. When commissioned, the *Tullibee* was painted in an overall Black (#82) scheme. The *Tullibee* was also camouflaged Measure SS-27F, a Black and Ocean Gray scheme that was authorized in 1953.

Experience gained with the *Tullibee* was incorporated into the new *Thresher* class. The *Tullibee* introduced a number of firsts for a U.S. submarine. She was the first to feature turboelectric drive, bow-mounted sonar array, and amidships torpedo tubes. Following 28 years of service, the *Tullibee* was decommissioned on 25 June 1988 and delivered to Bremerton, Washington, for disposal.

Tullibee (SSKN 597) was a one-of-a-kind, small nuclear-powered anti-submarine hunter-killer submarine. A Combustion Engineering S2C water-cooled reactor that produced 2,500 shaft horsepower powered the *Tullibee*. The protrusions on the bow and between the sail extension and rudder are Passive Underwater Fire Control Feasibility System (PUFFS) domes. The superstructure aft of the sail houses additional hydrophones. *(Elsilrac)*

In 1968 *Tullibee* was fitted with an additional PUFFS dome mid-ship on the sail extension superstructure. The *Tullibee* pioneered the bow-mounted sonar dome and four Mk 64 midship-angled torpedo tubes. *Tullibee* is camouflaged in the Measure SS-27F scheme. The submarine's name has been painted on the sail extension, and the hull number has been applied to the sail in White. *(U.S. Navy)*

PUFFS Development



(Above) Tullibee, now painted in an overall Black scheme, moves at high speed during a test out of Electric Boat, Groton, Connecticut, in the 1970s. All hull numbers and names have been removed to protect the identity of the sub, although the shape of *Tullibee* was unmistakable. As with many one-of-a-kind U.S. submarines, *Tullibee* was used to test new armament and electronic equipment that would eventually find its way to later submarines. *(Elsilrac)*

(Below) A starboard side view of *Tullibee* as she moves on the surface with an electronic mast and navigation periscope extended. *Tullibee* was designed with a 1,000-ton displacement, but with design changes displacement grew to 2,640 tons. She was launched in 1960 and decommissioned in 1988. *(Elsilrac)*

Thresher/Permit Class

The late 1950s and early 1960s witnessed a buildup of the U.S. nuclear submarine and surface fleet. The carrier *Enterprise* (CVN 65), cruisers *Bainbridge* (CGN 25) and *Long Beach* (CGN 9), plus the *George Washington* (SSBN 598), *Ethan Allen* (SSBN 608), and *Lafayette* (SSBN 616) class were all authorized, laid down, and launched during this timeframe.

The *Thresher* class was no exception to this almost frantic buildup. Authorized in the 1957 shipbuilding program, *Thresher* (SSN 593) was laid down at Portsmouth Naval Shipyard on 28 May 1958. *Thresher* utilized a modified submarine SCB-188 design from the improved *Skipjack* class. The first 10 of the *Thresher* class were 278.5 feet in length, had a beam of 31.6 feet and a draft of 28.42 feet. *Jack* (SSN 605) was the exception at 295.6 feet due to the installation of a modified power plant and General Electric machinery that consisted of twin contra rotating propellers on one sleeved shaft. To accommodate the modified machinery, the *Jack* was lengthened by 10 feet in the machinery room area.

On 9 April 1963, after an extensive refit at Portsmouth Naval Shipyard, the *Thresher* was performing a post availability shakedown, when she was lost, with all hands, off the coast of Maine. The suspected cause of the loss was faulty welding of the HY 80 steel hull. With the loss of the *Thresher*, the *Permit* (SSN 594) became the class leader. *Permit* was constructed by Mare Island Shipyard, as was her sister *Plunger* (SSN 595). In all, seven shipyards participated in the construction of the 14 *Thresher/Permit* class subs.

All of the class were fitted with the BQQ-2 active/passive bow-mounted array, similar to the suite fitted to the earlier *Tullibee*. The BQQ-2 consisted of the BQS-6 active sonar and the BQR-7 passive array. The bow-mounted sonar dictated the use of amidships-mounted torpedo tubes, two per side. The torpedo and missile launching system consisted of either the Mk 113 or Mk 117 fire control system. The Mk 117 was fitted to the *Permit*, *Plunger*, *Pollack* (SSN 603), *Dace* (SSN 607), and *Haddock* (SSN 621), while all others in the class were originally fitted with the Mk 113. The entire class was upgraded to the Mk 117 system during refits. The *Permit* class was fitted to carry the Mk 46 and the Mk 48 torpedo plus the UUM-44A, SUBROC stand off anti-submarine surface to surface missile (SSM) and the UGM-84 Harpoon anti-ship missile.

All of the *Thresher/Permit* class subs were powered by the proven Westinghouse S5W pressurized water-cooled reactor that developed 15,000 shaft horsepower to the single five-blade propeller. This gave the subs a submerged speed in excess of 30 knots, although the U.S. Navy official speed was 20 knots. Three different manufacturers produced steam turbines for the class. De Laval turbines were installed in the *Tinosa* (SSN 606), *Flasher* (SSN 613), *Greenling* (SSN 614), and *Gato* (SSN 615). Westinghouse turbines were fitted to *Thresher*, *Permit*, *Plunger*, and *Barb* (SSN 596); General Electric provided the balance.

The early *Permit* class submarine was 278.5 feet in overall length and had a sail that was 15 feet high with diving planes situated some 30 inches from the top. From *Flasher* (SSN 613) and on, the sail was raised to 20 feet, and the hull was lengthened by 13 feet to accommodate the machinery necessary to the fitting of the newly developed towed array assembly. *Flasher*, *Greenling*, and *Gato* were all fitted with SUBSAFE equipment, and they became the prototypes for the *Sturgeon* (SSN 637) class of new fast attack submarines. The SUBSAFE procedural and operational system was introduced following the loss of *Thresher*.

The *Permit* class was assigned to Submarine Squadron Three, San Diego, California, or Submarine Squadron Ten, New London, Connecticut. All of the *Permit*-class subs have been decommissioned, with the *Gato* being the last, having been delivered to Bremerton, Washington, on 24 April 1996 for breaking up and reactor storage.

Thresher (SSN 593) operates in the Atlantic Ocean on builder's sea trials with multiple extendables deployed from the sail. Tragically, she was lost with all hands off the coast of Maine on 10 April 1963 following post overhaul trials. The cause of the loss is unknown, but it is speculated that faulty welds could have caused the loss. Portsmouth Naval Shipyard constructed the *Thresher*. *(Portsmouth Naval Shipyard)*

With the loss of *Thresher* in 1963, *Permit* (SSN 594) became the lead boat in the class. The *Permit*, seen here, is moving in the San Francisco Bay area on 24 March 1962, just prior to her commissioning. *Permit* served with SUBRON 3 out of San Diego, California. The dark panel on the starboard dive plane is a nonskid area. *(U.S. Navy)*

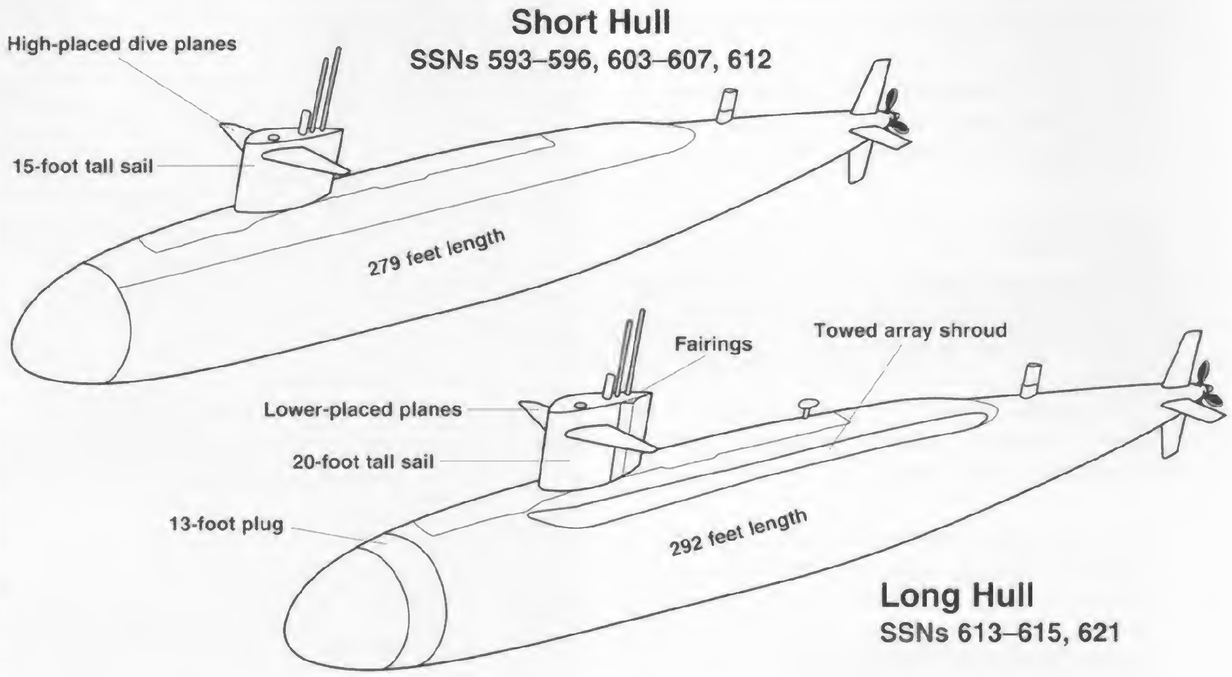
The captain and the sea watch man the sail and dive planes as *Plunger* (SSN 595) approaches Oahu, Hawaii, on 18 January 1963. *Plunger* was originally named *Pollock*, but the name was changed during construction. *Plunger* was decommissioned on 3 January 1990 after 30 years of service. *(U.S. Navy photograph by Bob Carlisle)*

Barb (SSN 596) on builder's trials in the Gulf of Mexico out of Ingalls Shipyard, Pascagoula, Mississippi, in 1963. Additional hydrophones have been added atop the forward sail area. *Barb* served with SUBRON 3, San Diego, California, until she was decommissioned on 20 December 1989. *(U.S. Navy)*

Stages have been placed on the upper hull superstructure for the launching of *Jack* (SSN 605) into the Piscataqua River at Portsmouth Naval Shipyard on 24 April 1963. *Jack* would soon be fitted with contra-rotating propellers and undergo four years of testing before she was commissioned on 31 March 1967. *(Portsmouth Naval Shipyard)*

In 1967, *Jack* was reconfigured with a single propeller that replaced the originally installed contra-props. *Jack* would go on to serve with SUBRON 10, New London, Connecticut. The twin-prop design had many problems, and the decision was made to install the standard five-blade prop. A temporary windscreen has been installed on the sail. *(U.S. Navy)*

Thresher/Permit Development



Tinosa (SSN 606) on sea trials in the Atlantic Ocean in 1964. *Tinosa* served with Submarine Squadron 10, New London, Connecticut. *Tinosa* was later fitted with a towed body shroud running along the port side of the hull. The floating wire antenna is still deployed out of the aft upper sail area. Two hydrophone domes are situated on the hull superstructure aft of the sail. *(U.S. Navy)*

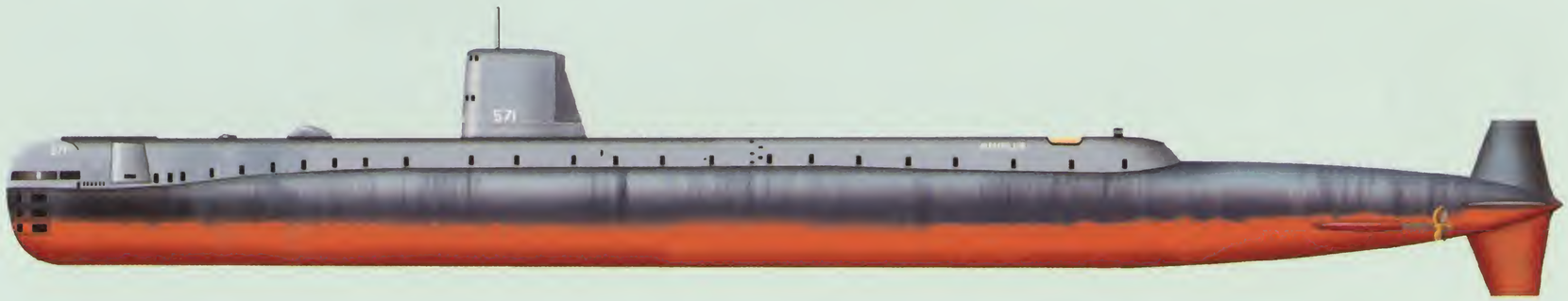
(Clockwise from upper right)
Guardfish (SSN 612), operating off the coast of Hawaii, was the last of the short-hull, short-sail *Thresher/Permit* class to be built, and the last nuclear attack submarine to be built by New York Shipbuilding. *Guardfish* would go on to serve with Submarine Squadron Three, San Diego, California. *(U.S. Navy)*

Dace (SSN 607) moves on the surface of the Gulf of Mexico with her deck awash during sea trials out of Ingalls Shipyard, Pascagoula, on 19 June 1964. *Dace* was the first of the *Permit* class to be decommissioned. The line formed on the hull that runs from under the port side sail-plane is the safety track used by deck hands to secure a lifeline to the submarine. *(U.S. Navy)*

A *Permit*-class submarine undergoes a test of the water pumps, operating at 4,500 pounds per square inch, for an emergency blow of all tanks. The sail-planes are angled up so a sail staging platform could be erected. Many lines have been rigged so the sub will not float away from the staging wharf. *(U.S. Navy)*

U.S. Nuclear Attack Subs in Color

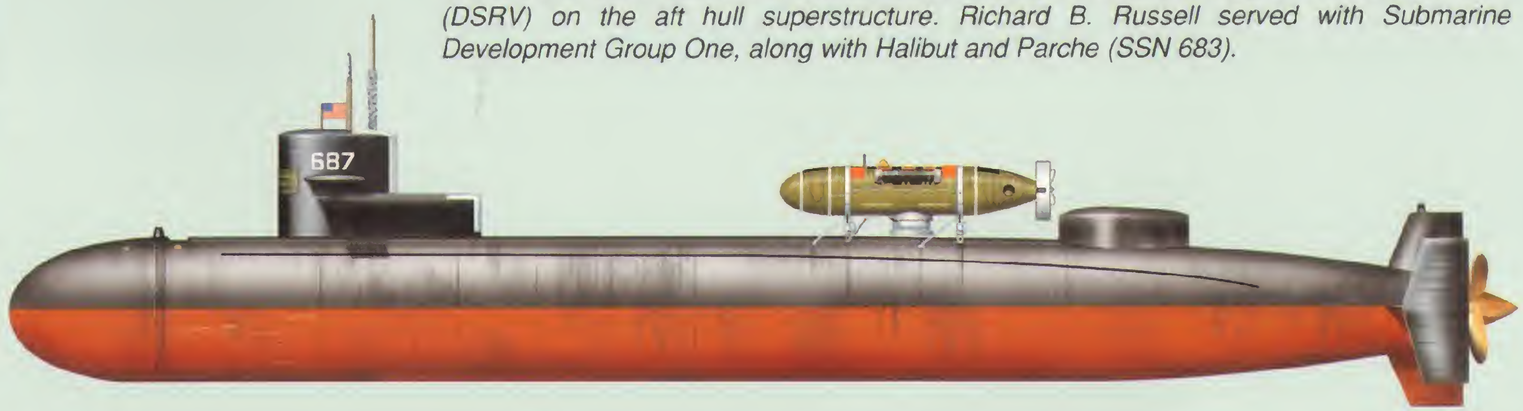
Nautilus (SSN 571) was the world's first nuclear-powered sub. The Nautilus employed a GUPPY (Greater Underwater Propulsive Power) type hull and sail.



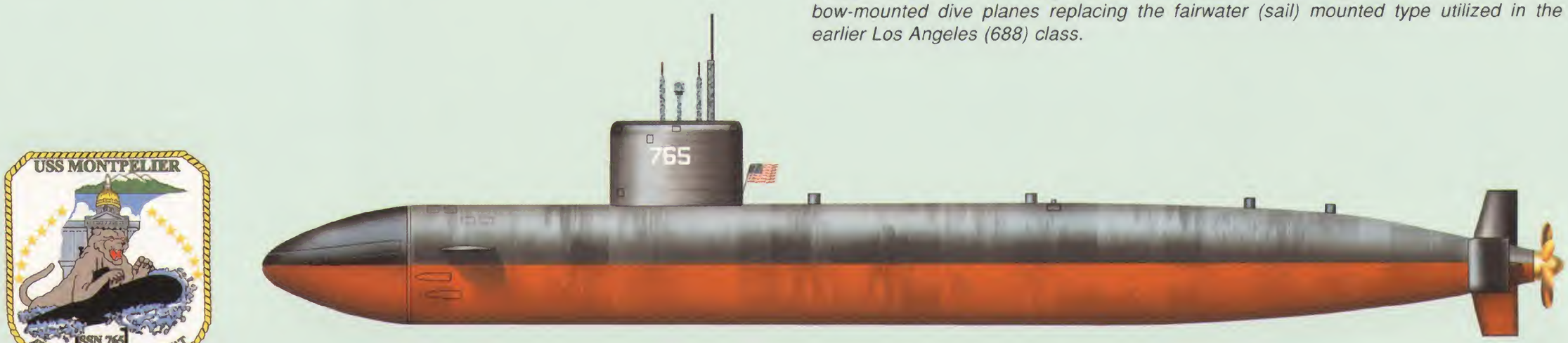
Seawolf (SSN 575) was the second nuclear-powered submarine constructed for the U.S. Navy. The Seawolf initially employed a liquid sodium-cooled reactor.

Halibut (SSGN 587) was fitted to transport and launch up to five LTV Regulus I surface-to-surface missiles. The Halibut was later converted to a covert action submarine when the Regulus program was cancelled in 1959.

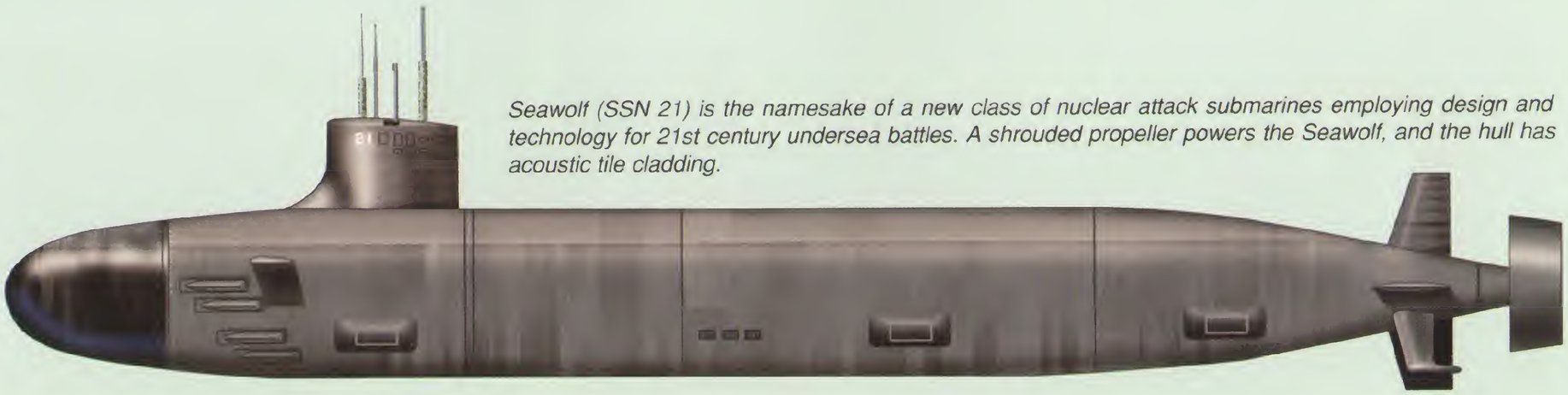
Richard B. Russell (SSN 687) was modified to carry a Deep Submergence Rescue Vehicle (DSRV) on the aft hull superstructure. Richard B. Russell served with Submarine Development Group One, along with Halibut and Parche (SSN 683).



Montpelier (SSN 765), designated as an "improved" Los Angeles class, is fitted with bow-mounted dive planes replacing the fairwater (sail) mounted type utilized in the earlier Los Angeles (688) class.

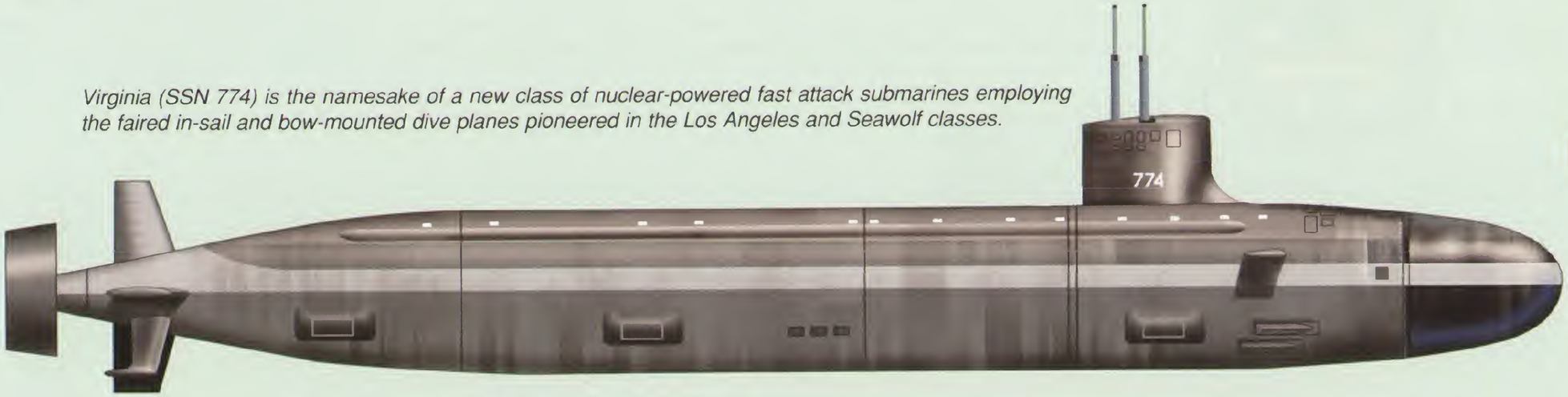


John Marshall (SSN 611) was a former fleet ballistic missile (FBM) submarine (SSBN) that was converted by modifying the missile tubes and installing a pair of Dry Deck Shelters to be used by SEAL and covert action teams.

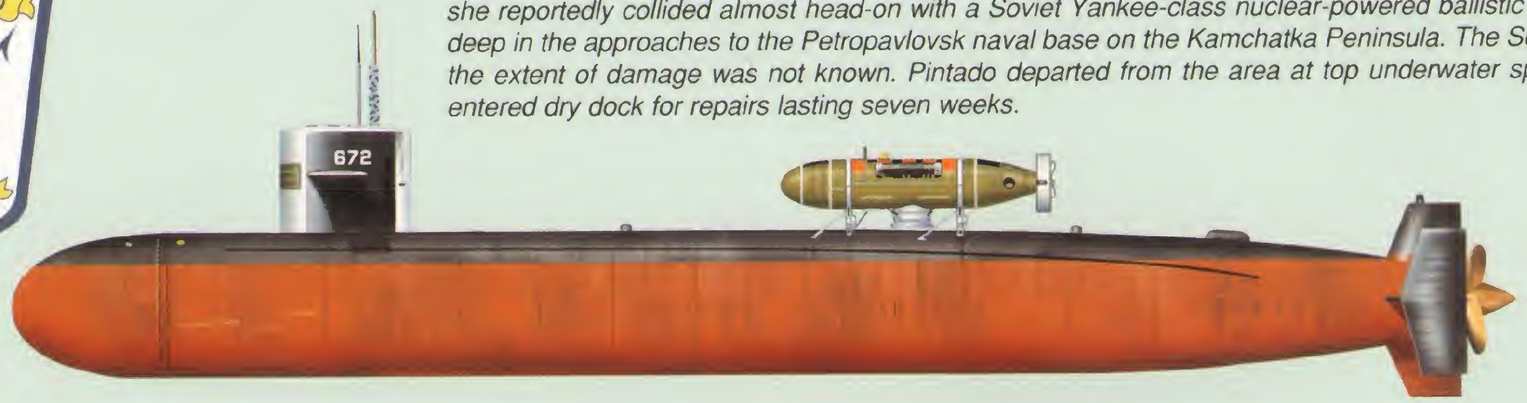


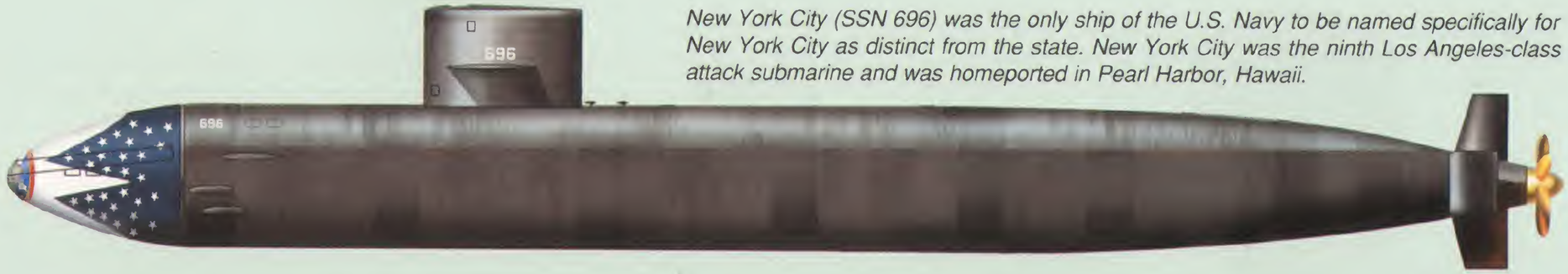
Seawolf (SSN 21) is the namesake of a new class of nuclear attack submarines employing design and technology for 21st century undersea battles. A shrouded propeller powers the Seawolf, and the hull has acoustic tile cladding.

Virginia (SSN 774) is the namesake of a new class of nuclear-powered fast attack submarines employing the faired in-sail and bow-mounted dive planes pioneered in the Los Angeles and Seawolf classes.



Pintado (SSN 672) was one of the Sturgeon-class attack submarines and the second ship in the Navy to bear the name. In May 1974, she reportedly collided almost head-on with a Soviet Yankee-class nuclear-powered ballistic missile submarine while cruising 200 feet deep in the approaches to the Petropavlovsk naval base on the Kamchatka Peninsula. The Soviet submarine surfaced immediately, but the extent of damage was not known. Pintado departed from the area at top underwater speed and proceeded to Guam where she entered dry dock for repairs lasting seven weeks.





New York City (SSN 696) was the only ship of the U.S. Navy to be named specifically for New York City as distinct from the state. New York City was the ninth Los Angeles-class attack submarine and was homeported in Pearl Harbor, Hawaii.

Honolulu (SSN 718) is the 24th Los Angeles-class fast-attack submarine. Designed for carrier escort, the Los Angeles-class submarine combines the most desired attack qualities: speed, silence, and powerful weaponry. Submarines in this class can be armed with Mk 48 and ADCAP torpedoes, and the Tomahawk cruise missile.

Seawolf-class nuclear attack submarine Jimmy Carter (SSN 23) honors the 39th president of the United States. President Carter is the only submarine-qualified man who went on to become the nation's chief executive officer, leader of the executive branch, and commander in chief of the armed forces.

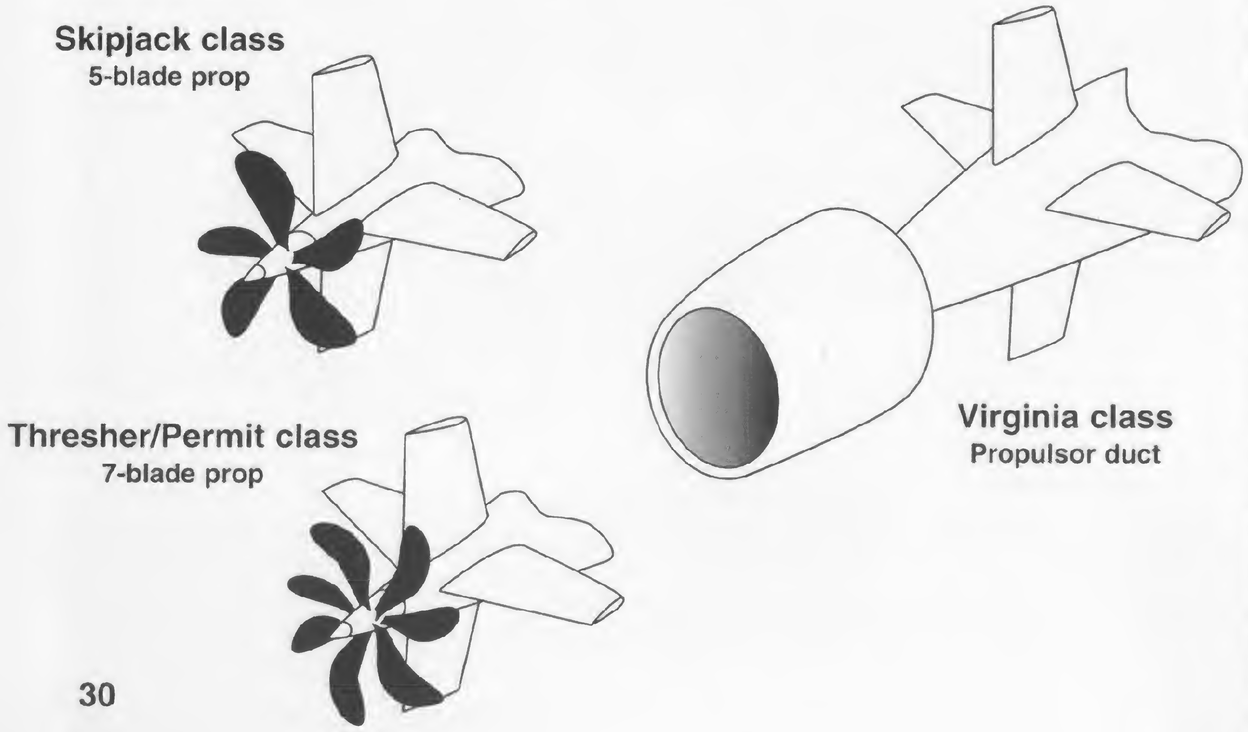
Greenling (SSN 614) makes "S" turns in the Atlantic during sea trials out of Electric Boat, Groton, Connecticut, in 1967. *Greenling* was the second of three long-hulled *Permit*-class subs to be built by Electric Boat. Due to various design changes, it took almost six years from keel laying to commissioning. *(Electric Boat)*

With the Stars and Stripes flying from the gaff, and deck crew awaiting instructions, *Haddock* (SSN 621) prepares to enter Subic Bay, Republic of the Philippines, on 25 August 1981. *Haddock* served with Submarine Squadron Three until she was decommissioned in 1992. Various hydrophones are situated on the deck, and the shroud for the towed sonar array runs along the port side of the superstructure. *(U.S. Navy)*

Gato (SSN 615) in the Atlantic on builder's trails in 1968. *Gato* was decommissioned on 25 April 1996, the last of the *Permit* class to be in commission. *Gato* served with Submarine Squadron Ten, New London, Connecticut, while in service. The submarine is "buttoned up" in preparations to submerge. *(Electric Boat)*

Crewmen and various civilians man their stations aboard *Haddock* (SSN 621) as it cruises along the coast of Mississippi while undergoing sea trials out of Ingalls Shipbuilding on 1 December 1967. *Haddock* was the last of the *Thresher/Permit* class to be constructed. The long-hull *Permits* had a 10-foot-longer hull and a 5-foot-taller sail than their short-hulled sisters. *(U.S. Navy)*

Prop Development



A port side view of *Haddock* under way in the Pacific Ocean on 6 June 1989. The Stars and Stripes fly at the staff as the surface watch man their stations. A temporary windscreen has been erected for the crew's protection. The light area on the port side sail-mounted dive plane is a nonslip area that would be used if it became necessary to have more men topside. *(U.S. Navy)*

Sturgeon Class

Following the loss of the *Thresher* in 1964, the Bureau of Ships began the modification of current submarines and incorporated SUBSAFE equipment in the design and construction of newer submarines to come. *Gato*, *Greenling*, and *Flasher* of the *Permit* class were modified to the SUBSAFE requirements, and they became the prototypes for the new *Sturgeon* class.

The *Sturgeons* from the lead boat *Sturgeon* (SSN 637) to *Billfish* (SSN 676) were 292.25 feet in length, and had a beam of 31.7 feet and a draft of 26 feet. From *Drum* (SSN 677) to the *Richard B. Russell* (SSN 687), the submarines grew to a length of 301 feet. The additional 11 feet was necessary to accommodate extra sonar and electronic gear.

The *Sturgeon* class would become the largest class of fast attack or fleet ballistic missile submarines built for the U.S. Navy until the *Los Angeles* class (688) of boats. The construction process was not, though, without incident. While the *Pogy* (SSN 647) was under construction at New York Shipbuilding, the U.S. Navy cancelled the contract and had the sub towed to Ingalls Shipbuilding at Pascagoula, Mississippi, to complete the construction process. The *Guitarro* (SSN 665) was being fitted out at San Francisco Bay Naval Shipyard, when she sank at her mooring in 35 feet of water. The accidental sinking caused a two-year delay and $25 million to repair. The cause of the sinking was shipyard workers deciding it was time for a lunch break.

The *Sturgeon* class was originally fitted with BQQ-2 active/passive sonar, but all were up-fitted with the improved BQQ-5 that was being manufactured by IBM for the *Los Angeles* class. A BQS-8 under-ice sonar was also fitted since one of the missions of the *Sturgeon* class was to keep the Northwest Passage open to friendly submarines. *Sturgeons* were also equipped with BPS-14 surface search radar and Mk 117 Mod-3 torpedo/missile fire control system.

The *Sturgeon* class was fitted with four 21-inch torpedo tubes, two per side located low on the hull side just aft of the bow area that could launch the Mk 48 and Mk 50 torpedoes. The normal load of 16 torpedoes could be carried; these would be supplemented by six SUBROC (UUM-44 A) nuclear-tipped rockets. All of the SUBROCs were removed by 1992 due to treaty obligations. Further armament included the Sub-Harpoon (UGM-84) and the modified Harpoon called the SLAM (Standoff Land Attack Missile). Most *Sturgeons* were equipped to handle the Tomahawk (UGM-109), submarine-launched cruise missile. The Tomahawks can be configured to attack land or sea targets and be equipped with nuclear devices or conventional weaponry.

An additional response to the loss of the *Thresher* was the construction of two deep-diving rescue vehicles called Deep Submergence Rescue Vehicles. Constructed by Lockheed, the DSRV-1 Mystic and DSRV-2 Avalon would be used to rescue submarine crewmen from a disabled submarine. DSRVs are constructed of high-strength HY-140 steel and they can dive to over 5,000 feet, well below depths associated with any U.S. nuclear submarine. Originally, four of the *Sturgeon* class — *Pintado*, *Hawkbill*, *Billfish*, and *Parche* — would be modified to carry the DSRV. The DSRVs are 50 feet in length and have a crew of four and can accommodate up to 30 survivors. The *Richard B. Russell* (SSN 687) was fitted with an experimental communications bustle aft of the sail to be used to test underwater communications.

The *Sturgeons* were all powered by the Westinghouse S5W pressurized water-cooled reactor that provided 15,000 shaft horsepower. The sub design was a modified SCB-188 A, a design used by the *Thresher* class, but with SUBSAFE modifications. The *Sturgeons* were a little slower than the *Skipjacks* and *Permits* since they were larger and had greater displacements, but they used the same reactor. Speeds, though, were still rated 20-plus knots surfaced and 30-plus knots submerged. A single seven-blade screw was fitted.

The *Redfish* (SSN 680) was renamed the *William H. Bates* on 25 June 1971, deviating from the long-standing practice of naming U.S. Navy attack submarines after creatures of the sea. The policy was also changed for the *L. Mendel Rivers* (SSN 686) and *Richard B. Russell* (SSN 687). The *Parche* (SSN 683) underwent a conversion to a "project boat" and was configured with a superstructure on the hull just forward of the sail and a smaller one just aft of the sail, as well as a small remote-controlled vehicle on the aft upper hull. The *Parche* remains today a highly classified submarine, even following her decommissioning. The *Parche* was awarded five Presidential Unit Citations and three Navy Unit Citations for her clandestine service.

All of the *Sturgeon* class have been decommissioned and their hulls and reactors delivered to Bremerton, Washington, for disposal and storage, most having served over 30 years in the security of the United States.

Sturgeon (SSN 637) was the lead boat in the class. She was built by General Dynamics, Electric Boat Division, and launched on 26 February 1966. The *Sturgeon*-class subs were improved *Thresher/Permit*-class boats. A Westinghouse S5W (a 15,000 SHP water-cooled pressurized nuclear reactor) powered the *Sturgeon* class. The track running along the port side hull is the track for the crew's lifeline. *(U.S. Navy)*

Whale (SSN 638) sits in the ice at the North Pole on 6 April 1969. This surfacing at the North Pole was to commemorate the 60th anniversary of Rear Adm. Richard E. Byrd's historic event of reaching the pole in 1909. All of the *Sturgeon* class had sail-mounted dive planes that could be rotated to the vertical to enable the sub to break through the ice pack. *(U.S. Navy)*

U.S. Navy and British sailors explore the Arctic ice cap while conducting the first U.S./British coordinated surfacing at the North Pole. The subs (from left) are the nuclear attack submarines *Sea Devil* (SSN 664), *Billfish* (SSN 676), and the fleet submarine HMS *Superb* (S 109). *(U.S. Navy)*

A chief petty officer (CPO) gives instructions to the helmsmen aboard *Pargo* (SSN 650) as Cmdr. David W. Hearding, the sub's commander, looks through the navigation periscope as the sub is under way maneuvering under the ice pack north of the Arctic Circle on 6 April 1991. The interior of a nuclear fast attack submarine is very crowded, with no space wasted. *(U.S. Navy)*

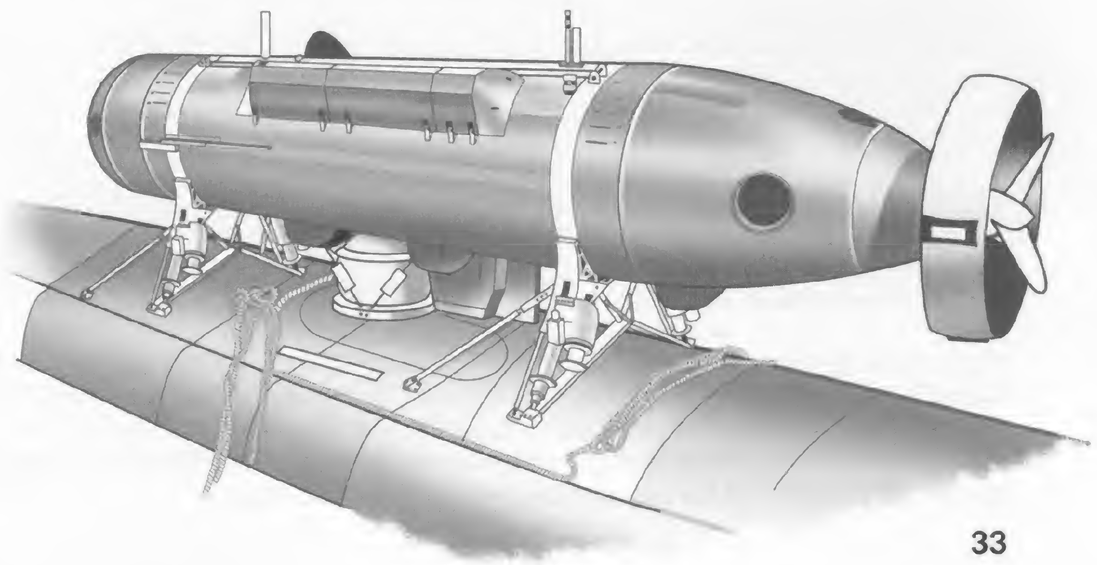
Tautog (SSN 639) breaches the surface during an emergency surfacing exercise. A full one-third of the hull is out of the water. An exercise of the type is designed to get the sub to the surface in as little time as possible. *Tautog* was decommissioned in 1997 after 29 years of service. *(U.S. Navy)*

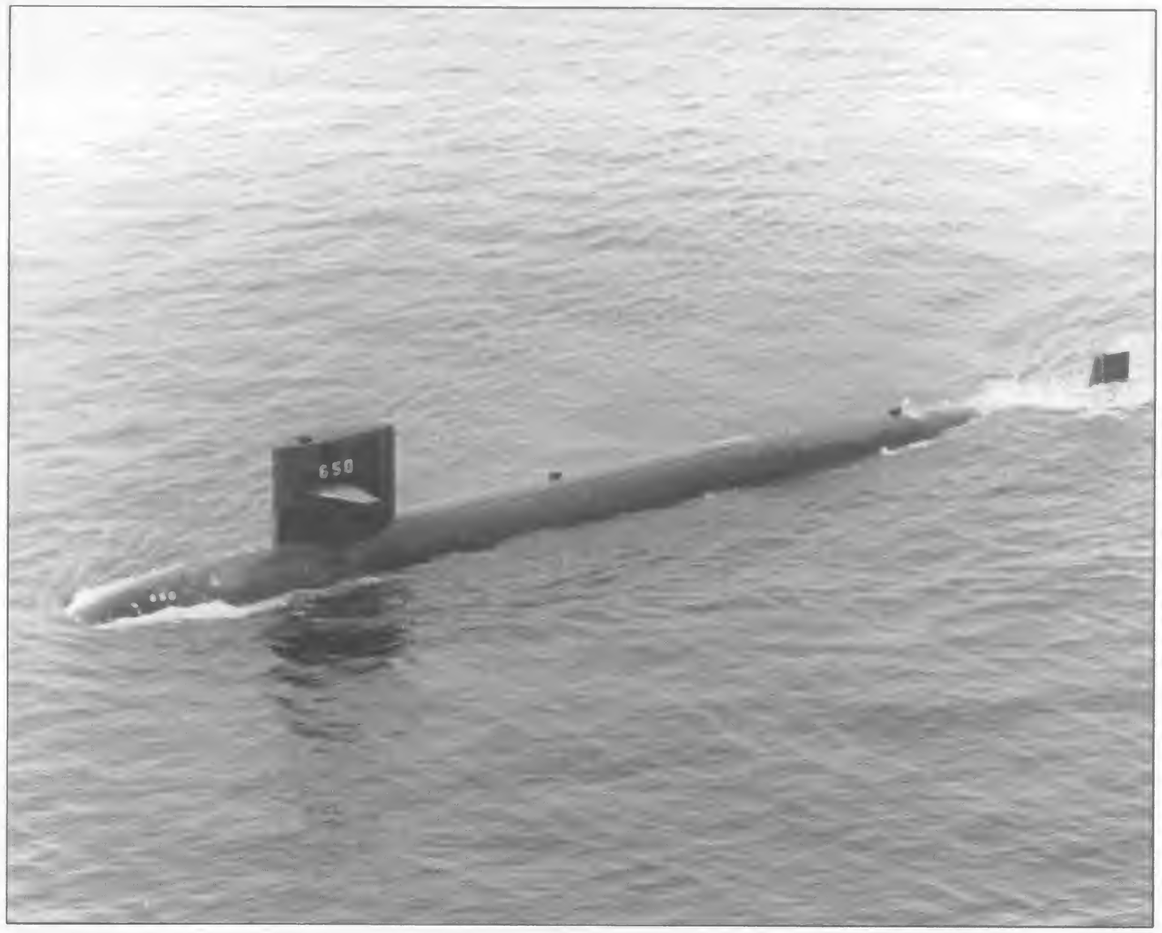
Queenfish (SSN 651) moves at high speed on the surface during builder's trials in the Atlantic in 1968. Newport News Shipbuilding constructed *Queenfish*. The vents at the top of the sail are for the exhaust for the auxiliary Fairbanks Morse onboard diesel engine. A temporary windscreen has been erected, but the sailor on sea watch is still holding his cap. *(U.S. Navy)*

A Sikorsky SH-3D Sea King from Helicopter Anti-Submarine Squadron Four (HS-4) hovers over a *Sturgeon*-class submarine in the South China Sea off the coast of South Vietnam in 1970. The operation was called to airlift a seriously ill crewman, who was standing on the deck of the submarine, to the *Kitty Hawk* (CV 63) for treatment. *(Nicholas J. Waters III)*

Deep Submergence Rescue Vehicle

DSRV placement on Sturgeon class





(Clockwise from above)
Finback (SSN 670) runs on the surface during builder's trials in the Atlantic on 30 October 1969. The *Finback* was constructed by Newport News Shipbuilding and served with Submarine Squadron Six, Norfolk, Virginia. The Stars and Stripes are flying from the identification beacon light staff. *Finback* was named to honor the World War II fleet submarine *Finback* (SS 230). *(U.S. Navy)*

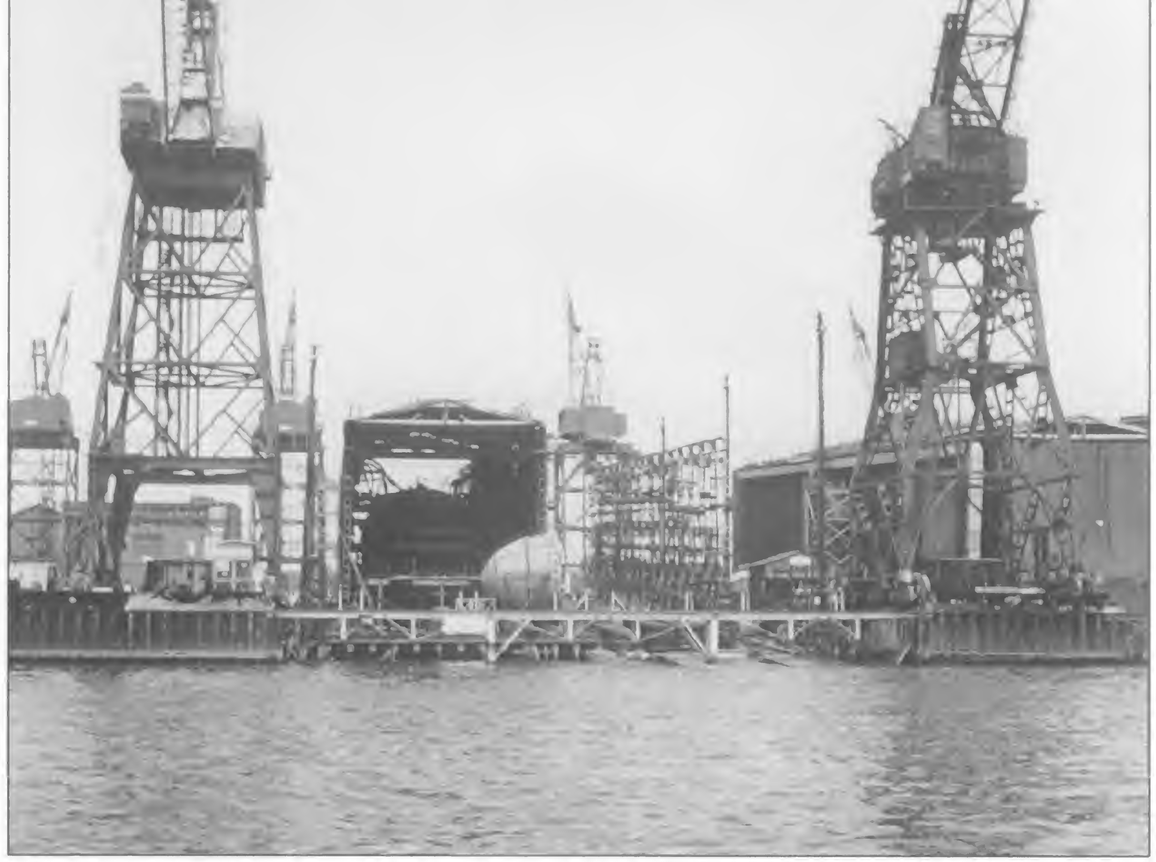
Water pours from the sail of *Sea Devil* (SSN 664) as she surfaces off the Virginia coast during a sea power demonstration in honor of NATO's 20th anniversary in 1969. The attack periscope and direction finder antenna are extended out of the sail. As soon as the water clears the sail, the sea watch will be manned. *(U.S. Navy)*

Pargo (SSN 650) on sea trials in 1967. The protrusions on the hull are hydrophone domes. *Pargo*, *Whale* (SSN 638), and *Sargo* (SSN 583) operated in the North Pole area under the ice pack, mapping and collecting geographical data for future underwater explorers. The *Pargo* was constructed by Electric Boat and operated out of Bremerton, Washington, escorting fleet ballistic missile (FBM) subs until her decommissioning in 1995. *(U.S. Navy)*

Pintado (SSN 672) with the Deep Submergence Rescue Vehicle Mystic (DSRV-1) embarked on the aft upper hull in 1977. *Pintado* acted as a mother ship for the Mystic and operated out of San Diego, California, with Submarine Squadron Eleven. The DSRV could be used to rescue crewmen from a disabled submarine or insert SEAL teams on clandestine missions. The White painted area on the sail and dive planes would be used as a guide for the DSRV operator. *(U.S. Navy)*

Billfish (SSN 676) moves on the surface in 1985 following an overhaul and refitting. The horn shroud on the edge of the sail has been opened. The light-colored oval at the water break is a messenger buoy that would be deployed in the event the sub became disabled. *Billfish* was one of the last of the short-hull *Sturgeon* class to be built. *(Electric Boat)*

A stern forward view of *Trepang* (SSN 674) as she departs from her base at Naval Submarine Base New London, Connecticut, in 1985 while serving with Submarine Squadron Ten. *Trepang* was commissioned on 14 August 1970 and decommissioned on 4 January 1999. *(Electric Boat)*



(Clockwise from above)
Billfish (SSN 676) arrives at Naval Station Rota, Spain, with the Deep Submergence Rescue Vehicle (DSRV-2) Avalon embarked in 1992. *Billfish* was participating in the NATO Exercise Sorbet Royal 92. Aircraft and shipbuilder Lockheed constructed the DSRV Avalon. All of the deck crew are wearing red personal floatation devices (PFDs) and rubber-soled safety deck shoes. The White-painted area on the sail and dive planes will show up underwater when lighted by the DSRV operator. *(U.S. Navy)*

A *Sturgeon* class, probably either *Sea Devil* (SSN 664) or *Hammerhead* (SSN 663), under construction in a covered assembly way at Newport News, Virginia, in 1966. The bow nosecone that covers the spherical sonar array can be seen on the way just above the waterline. The submarines are constructed under cover, called hangars, to prevent viewing from spying space satellites. The hangar to the right has all sides covered with curtains, while the left side hangar is open at both ends. *(Terry Love)*

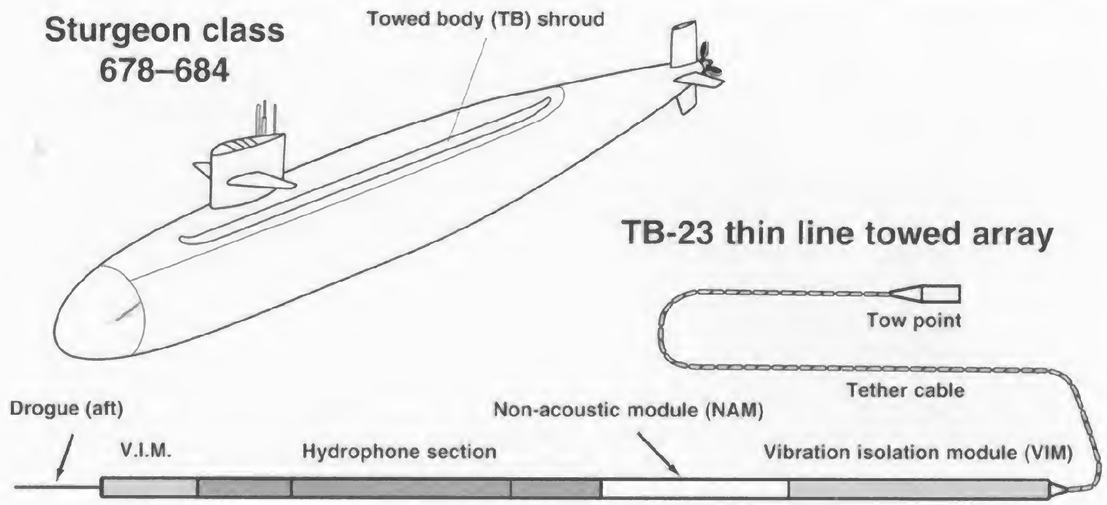
Billfish departing Rota, Spain, in 1992, to enter into exercises during Sorbet Royal 92. *Billfish* was attached to Submarine Squadron Ten, Norfolk, Virginia. The staining at the rear of the sail is caused by diesel exhaust. *(U.S. Navy)*

Parche (SSN 683) leaves the Hawaiian Islands configured as a "project" submarine in the 1990s. The configurations on the upper forward hull and the aft hull remain as highly classified items. *Parche* replaced *Halibut* as the main covert operations vehicle, and she was in turn replaced by *Jimmy Carter* (SSN 23) in that role. *(U.S. Navy)*

Crewmen examine the sail and the dive planes while *Billfish* is surfaced at the North Pole in 1987. The dive planes on *Sturgeon*-class submarines are able to rotate to enable the sub to break through the ice cap in the Arctic. Permanent ladders have been welded to both sides of the sail area for use by the crew when they are unable to use the hull-mounted hatches. *(U.S. Navy)*

Billfish is being secured to a wharf at Rota, Spain, prior to exercises and training in the Atlantic. The lighter-colored area, in line with the sail-mounted dive planes, is the housing for the Avalon (DSRV-2). The circle painted on the forward hull area is an escape trunk that will be used in conjunction with the DSRV-2 Avalon. Safety rails have been placed atop the sail for the sea watch. *(U.S. Navy)*

Towed Array Development



(Clockwise from upper left)
The last of the *Sturgeon* class, the long-hull *Richard B. Russell* (SSN 687) was used by Submarine Development Group One, Vallejo, California, as a test submarine for the *Los Angeles* class. A BQR towed array sonar shroud has been fitted to the port side superstructure, an experimental bustle emergency communications buoy has been placed aft of the sail, and an experimental hydrophone dome has been installed on the upper aft hull. A DSRV would have been hosted over an escape trunk on the aft upper hull area. *(U.S. Navy)*

Crew members stand on the sail and diving planes of the nuclear-powered attack submarine *Shark* (SSN 591) as it is towed through the Miraflores Locks of the Panama Canal. The submarine is en route to the Pacific Ocean. *(U.S. Navy)*

Batfish (SSN 681) on the surface of the Gulf of Mexico during Exercise Advance Phase III off the coast of Florida in 1986. Personnel from the *Batfish* are being transferred, by way of a whaleboat, to the guided missile destroyer *Scott* (DDG 995). Sonar operators from both ships will be jointly trained in anti-submarine warfare. *(U.S. Navy)*

Narwhal

The *Narwhal* (SSN 671) was built specifically to test the General Electric S5G natural circulation reactor that was water pressurized. The reactor cooling plant uses natural hot to cold circulation in place of the somewhat noisy primary pump type system. The reactor produces 17,000 SHP that drives two General Electric steam turbines. The reactor concept was used to power the *Los Angeles* and *Ohio* classes of nuclear-powered submarines. The *Narwhal* utilized a seven-blade propeller.

The hull of the *Narwhal* was similar in shape to the *Sturgeon* class and employed the SCB-245 submarine design; it was 314.6 feet in length, and it had a beam of 33 feet and a draft of 27 feet. Displacement was rated at 4,749 tons surface and 5,350 tons while submerged.

The *Narwhal* was fitted with four 21-inch torpedo tubes mounted two per side in the forward side hull area. The tubes could handle the Mk 48 and Mk 50 torpedoes as well as the Harpoon and SUBROC missile system. To handle torpedo and missile launching, the Mk 117 Mod fire control was fitted along with the BQQ-2 sonar suite. The BQQ-2 was upgraded to the BQQ-5 during an electronics overhaul. An under-ice BQ5-8 navigation sonar set was fitted for operations under the Arctic ice. For surface search, navigation and fire control, a Raytheon BPS-14, I/J band radar system was fitted. The antenna for the radar system was of the twin plane type that retracts into the sail.

The *Narwhal* was fitted with an experimental "turtleback housing," the function of which has remained classified. The housing appears to have contained either a remote-controlled vehicle or a new type of towed body array. The *Narwhal* was also used to test the starboard side fitted fairing that covers the storage/launch tube for the TB-16 towed array assembly that was later fitted to the *Los Angeles* class of fast attack submarines.

The *Narwhal* was undergoing a dockside overhaul while stationed with Submarine Squadron Four (SUBRON 4), Naval Submarine Base, Charleston, South Carolina, in 1989 when Hurricane Hugo was approaching. Permission was granted to the captain by the Commander of Submarine Group Ten, Rear Adm. Arlington F. Campbell, to submerge in the harbor to ride out the impending storm, thus averting any damage. The *Narwhal* rode out the storm, with only the sail protruding out of the water. When the hurricane passed, the *Narwhal* surfaced, she returned to dockside, and the refit continued, with no harm having come to the submarine.

The *Narwhal*, although basically a project boat, was fully combat capable, and she served with the Sixth Fleet in the Mediterranean Sea area. The *Narwhal* was commissioned 12 July 1969 and decommissioned on 1 July 1999, after 30 years of service. Scheduled to be cut up for scrap, she will be preserved as a museum in Newport, Kentucky, in 2007. When opened, it will be the only U. S. Navy nuclear-powered submarine on display open to the public.

Narwhal (SSN 671) was fitted with a structure, called a "turtleback," on the aft upper hull to handle either a remotely controlled underwater vehicle or an experimental towed array assembly. This system was installed during an extended three-year refit period that began in 1989. The various small protrusions on the upper hull superstructure are hydrophones. The helical antenna, attack and observation periscopes are extended out of the sail. *(U.S. Navy)*

When Hurricane Hugo hit Charleston, South Carolina, in September 1989, *Narwhal* was undergoing dockside overhaul and refit. Permission was granted to the captain of *Narwhal* by Rear Adm. Arlington F. Campbell, commander of Submarine Group Ten (SUBGRP 10), to submerge in the Charleston Naval Shipyard harbor to prevent any damage to the submarine. *(Rear Adm. Arlington F. Campbell)*

Glenard P. Lipscomb

The *Glenard P. Lipscomb* (SSN 685), like the *Narwhal*, was a one-off prototype to test new propulsion and machinery. In the case of the *Lipscomb*, the test involved the use of a General Electric turboelectric drive system.

The *Lipscomb* was fitted with twin turbine electric drives that significantly cut down on noise generated by the propulsion system. The turboelectric drive, called TEDS for Turbo Electric Drive System, though, was much larger than the steam turbine type and not as mechanically efficient; therefore, speed suffered as a consequence.

The *Lipscomb* was constructed using submarine design SCB-302 that was a modified *Sturgeon*-type hull, but much more cylindrical in shape. She was laid down on 5 June 1971 at General Dynamics, Electric Boat Division, Groton, Connecticut, and launched on 4 August 1973. After a year of testing, the *Lipscomb* was declared fit for fleet service.

The hull of the *Lipscomb* was 365 feet in length, with a beam of 31.7 feet and a draft of 31 feet. Displacement was rated at 5,813 tons surface and 6,480 tons submerged. The size and displacement were very close to the weight class and dimensions of the *Los Angeles* class.

Due to the size and displacement and relatively low power output of the Westinghouse S5W A reactor, submerged speed was rated at 25 knots. The power plant chosen was a derated Westinghouse reactor that produced 12,000 SHP, down from the 15,000 SHP produced by the S5W reactor and used in the *Skipjack*, *Thresher*, and *Sturgeon* classes. The reactor was derated to coincide with the TEDS power rating.

The *Lipscomb* was fully combat capable and was armed with four 21-inch torpedo tubes, two per side mounted on the lower hull just aft of the bow. The tubes were fitted to launch the Mk 48 and Mk 50 torpedoes, and the UUM-44A SUBROC. In 1981, the Mk 117 fire control system replaced the Mk 113 system that enabled the *Lipscomb* to launch the UGM-84 Harpoon missile system. The IBM BQQ-5 sonar suite with conformal array was positioned in the bow. Plans to add the Tomahawk Land Attack Missile System were shelved.

The *Lipscomb* last served with Submarine Squadron Six (SUBRON 6), Norfolk, Virginia. On 11 July 1990, the *Lipscomb* was decommissioned, her service life and usefulness having ended.

Like a lot of other ships, the *Glenard P. Lipscomb* was given a nickname; its moniker was "Lipscomb Fish." Information gained in the development, testing, and fleet service was utilized to develop the *Los Angeles* class.

Glenard P. Lipscomb (SSN 685) in the Atlantic on 22 November 1974 during builder's trials out of Electric Boat Division of General Dynamics. *Lipscomb*, following commissioning, would serve with Submarine Squadron Six (SUBRON 6), Norfolk, Virginia, until she was decommissioned on 11 July 1990. *(U.S. Navy)*

Glenard P. Lipscomb was designed as an experimental submarine to test the feasibility of using the General Electric silent machinery called the Turbine Electric Drive System (TEDS) and a new quiet reactor that had been designed for the new *Los Angeles* (688) class. The TEDS system proved to be too large and too heavy to be practical in an attack submarine. *Glenard P. Lipscomb* carried the nickname of "Lipscomb Fish." *(U.S. Navy)*

Los Angeles Class

The U.S. Congress in 1970 authorized the construction of three fast attack nuclear submarines that would come to be known as the 688 or *Los Angeles* class. Newport News Shipbuilding was chosen to build the first two boats, *Los Angeles* (SSN 688) and *Baton Rouge* (SSN 689), while General Dynamics, Electric Boat, built the third, *Philadelphia* (SSN 690). All keels were laid down in 1972, and the *Los Angeles* was commissioned on 13 November 1976. An early decision by the U.S. Navy limited the construction of this new class to just two yards, Newport News and Electric Boat.

The hull of the *Los Angeles* class utilized submarine design SCB-303 and was a marked departure from the teardrop shape of the earlier classes. The shape was that of a torpedo. The new hull was built in a cylinder shape with the bow providing the streamlining. The hull was constructed of prefabricated 33-foot plugs. The plugs were welded together to build the hull that was 360 feet in length. The cylinder shape was almost as efficient as the teardrop shape pioneered by the *Albacore*. The 688 boats had a draft of 32 feet and displaced 6,135 tons surfaced and 6,927 tons submerged.

Phoenix (SSN 702) on the surface in the Atlantic in 1993 while serving with SUBRON 8, Norfolk, Virginia. The launch/recovery shroud is located along the topside of the hull superstructure. The darker area on the spine of the hull is the nonslip area for use by the crew. The attack and navigation periscopes are extended as well as the telemetry mast. *(U.S. Navy)*

The first 39 boats in the 688 class were constructed utilizing sail-mounted diving planes. Beginning with the *San Juan* (SSN 751), the diving planes were moved to the forward hull area just aft of the bow. The move was made so that the sail area could be strengthened for under-ice operations. The bow-mounted planes could be fully retracted into the outer hull superstructure for close-in maneuvering. The sail or fairwater contained all of the extendables such as the periscopes, antennas, and snorkel. The 688 with bow-mounted planes was designated as I 688, the "I" for Improved. The I 688 class from the *San Juan* (SSN 751) and on were fitted with rubberlike cladding to reduce noise and make the hull more hydrodynamic.

All of the 688 class were fitted with four 21-inch torpedo tubes, with the exception of the "project" boat, *Memphis* (SSN 691), which was fitted with 30-inch tubes as a test for the *Seawolf* class. A new hydraulic handling system aids in the torpedo/missile handling. The 688 class subs carry the Mk 48 and Mk 50, and before 1992 they carried the SUBROC, anti-submarine missile. The Harpoon and Tomahawk missile systems were also carried.

During Operation Desert Storm in 1991, the *Pittsburgh* (SSN 720) and the *Louisville* (SSN 724) launched Tomahawk (UGM-109) Land Attack Cruise Missile at high-value targets inside the territory of Iraq. Most found their targets, though a few though were shot down. The Tomahawks can be launched either from the torpedo tubes or from the Vertical Launch System (VLS) that had been fitted to *Providence* (SSN 719) through the *Cheyenne* (SSN 773). There were 12 vertical launching tubes on the 688 class subs that were so equipped.

To handle all the installed missile and torpedoes, the Mk 117 Mod 3 fire control system was employed. This system is now the standard, replacing the Mk 113 in earlier boats. For surface search, the Sperry BPS-15A radar was installed. The extensive spherical sonar suite in the bow was the BQQ5A (V) passive/active search and attack sonar. For under-ice operations, the BQS-15 sonar array was fitted. The BQS-15 was also utilized for close-range operations. For defensive operations, the BQR-23/25 thin wire towed array and the TB-16D passive towed array were used.

The 35,000 horsepower General Electric natural circulation, pressurized S6G reactor powered all of the 688 class. The S5G was developed from the D2G type found in the guided missile frigate *Bainbridge* (DLGN 25). The reactor uses natural circulation for slow-speed operations and pumps for high-speed operations.

The reactor provides steam for the twin-geared turbines that drive the single seven-blade propeller. Due to the amount of horsepower available and the sleek hull design of the 688 class, they have a flank submerged speed of well over 30-plus knots. The high-strength hull design enables the 688s to dive well over 1,400 feet, although they are rated at 400-plus feet by the U.S. Navy.

The *Los Angeles* class consisted of 62 boats when the last one, the *Cheyenne* (SSN 773) was commissioned. By 2007, 12 of the 688 class had been decommissioned as the newer *Seawolf* and *Virginia* class came on line.

The 688 boats contributed to the security of the sea lanes in all oceans and will continue to serve until at least until 2017.

Los Angeles (SSN 688) was the lead boat in the class and was built by Newport News Shipbuilding, Newport News, Virginia, and launched on 6 April 1974. The 688-class subs are 360 feet in length and are powered by a General Electric S6G reactor that produces 35,000 horsepower. *Los Angeles* serves with SUBRON 7, Pearl Harbor, Hawaii. *(U.S. Navy)*

A U.S. Navy Sikorsky SH-60F Ocean Hawk accompanies the *Honolulu* (SSN 718) in the Pacific. The helicopter is from Antisubmarine Squadron Four (HS-4) off the fleet carrier *Kitty Hawk* (CV 63). *Honolulu* and the Ocean Hawk will soon participate in anti-submarine exercises off the Hawaiian Islands. *(U.S. Navy)*

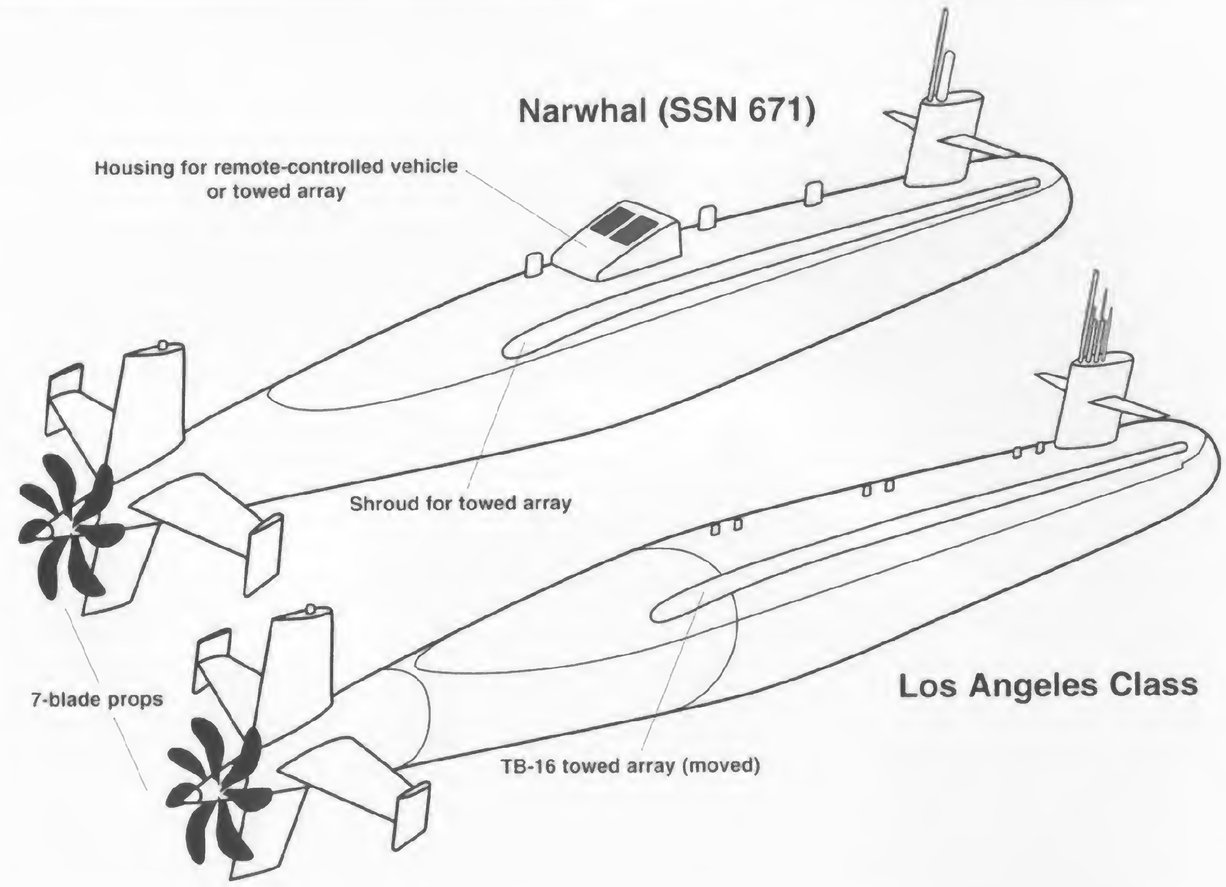
The *Salt Lake City* (SSN 716) moves down the James River, Virginia, in 1984, as the deck crew prepares the submarine for underwater operations. The hatches will soon be secured, and the railings on the sail for the sea watch will be removed. The device atop the vertical rudder is the stern navigation light. *(U.S. Navy)*

Lookouts on sea watch begin to secure the sail area as preparations for a dive are being made aboard *Olympia* (SSN 717). A Jacob's ladder has been deployed over the starboard side of the sail so a crewman could secure the temporary wire safety rails. The attack and navigation periscopes are extended out of their camouflaged shrouds. *(U.S. Navy)*

(Above) The sea watch, which usually consisted of an enlisted grade lookout, the captain, and the navigation officer, man the sail of the *Newport News* (SSN 750). The White-painted geometric design on the hull, aft of the sail, is an escape trunk that would be used by an escape bell or a DSRV in the event of a sinking. *(Newport News Shipbuilding)*

(Right) A pair of commercial tugs at Naval Submarine Base San Diego, California, pushes *Chicago* (SSN 721). *Chicago* wears a traditional flower garland to celebrate her safe return home from the Persian Gulf region in support of Operation Desert Storm. *Chicago* is fitted with the Vertical Launch System (VLS) that is capable of launching the Tomahawk cruise missile. *(U.S. Navy)*

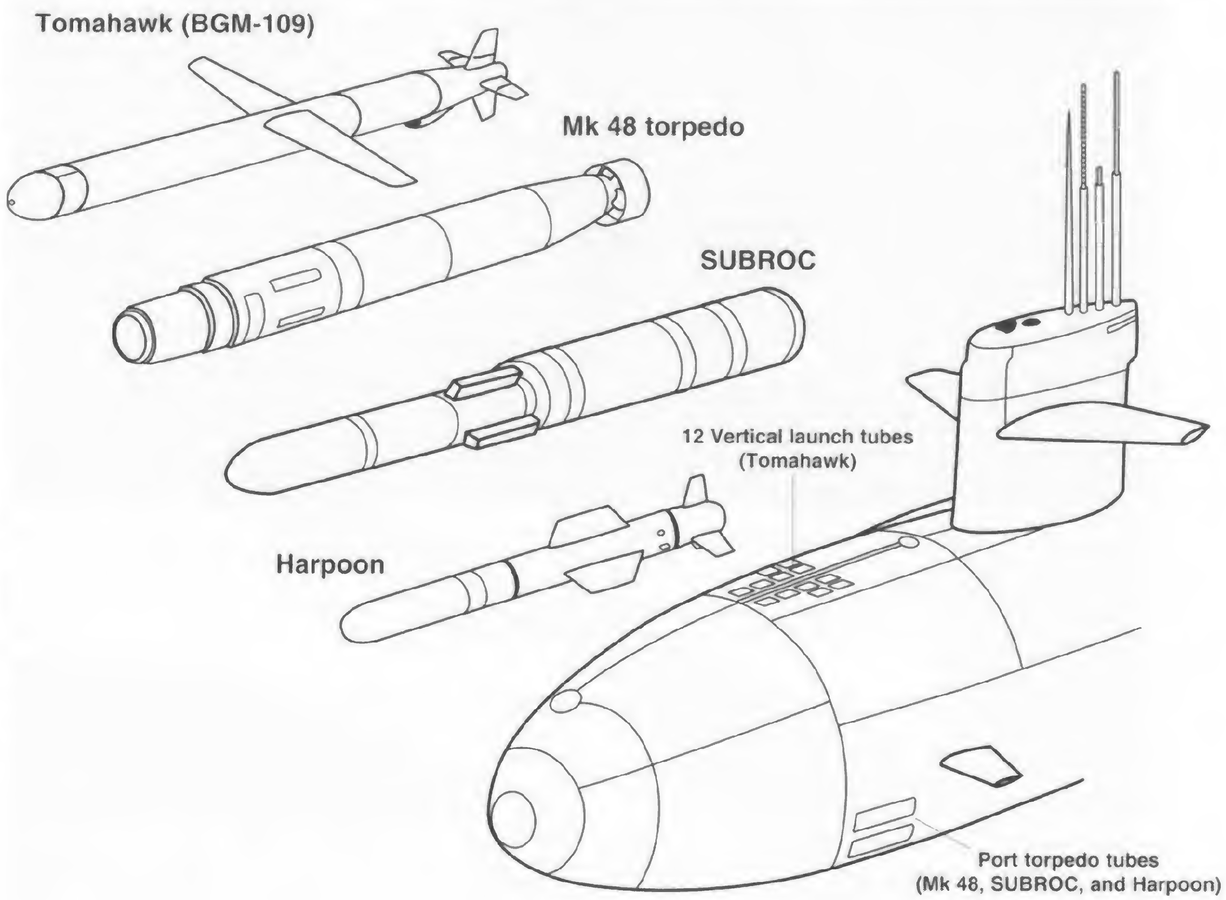
Towed Array Location Development



Miami (SSN 755), without the hull number applied to the sail, navigates on the surface, sea watch in place. The singular round area on the hull is the location of a distress buoy that would be deployed in the event of an emergency. The lighter-colored area on the upper forward area of the sail is the MIDAS mine detection and navigation sonar. *Miami* was commissioned in 1989. *(General Dynamics)*

San Juan (SSN 751) under way in Chesapeake Bay, Virginia, in 1988 with the sea watch posted, just prior to her commissioning. *San Juan* was the first of the new Improved 688 class that had the dive planes moved to the bow area from the sail. The light area below the hull number is the red port side navigation light. *(U.S. Navy)*

Los Angeles-Class Weapons



The *Montpelier* (SSN 765) on sea trials on 15 November 1992 in the Atlantic. The attack periscope is up for surface navigation. The stained area on the upper aft sail is from diesel exhaust and salt water. The hull number will soon be painted out when she joins the fleet, and magnetic letters would be applied at the discretion of the captain when in port. *(U.S. Navy)*

Greeneville (SSN 772) carries an Advanced SEAL Delivery System (ASDS) on the aft hull area. The ASDS carries a crew of three and can accommodate up to 20 SEALs or other covert team members. The ASDS is fitted to an escape trunk and is capable of hosting another ASDS or DSRV atop its hull in the event of an emergency situation. *(Northrop Grumman)*

Cheyenne (SSN 773) was the last of the Improved Los Angeles class of attack submarines, and she was built by Newport News Shipbuilding. The Stars and Stripes and a Newport News Shipbuilding company flag flies from the staff. The temporary rail is erected for the safety of the sea watch and will be removed before the submarine submerges. *(Newport News Shipbuilding)*

Seawolf Class

When the *Seawolf* (SSN 21) was launched from the ways at Electric Boat in 1995, it marked a new era in the U.S. nuclear fast attack submarine force. The design was so new and cutting edge that the normal numbering of the hulls was broken, and the number 21 was inserted to reflect the 21st century. The *Seawolf* was designed to counter the new Soviet submarine threats, one that never materialized.

The *Seawolf* was authorized on 9 January 1989 in a contract that was valued at $726 million. Electric Boat also constructed the second boat, *Connecticut* (SSN 22). By naming the number-two boat *Connecticut*, the U.S. Navy again deviated from the usual practice of naming submarines after creatures of the sea or civilians who had a direct impact on the submarine service, and used the name of a U.S. state. The third, and last boat in the class was the *Jimmy Carter* (SSN 23), named to honor the 39th president of the United States, and the only president who was a submariner, having served as a reactor officer. Electric Boat also constructed the *Jimmy Carter.*

The *Seawolf* class was envisioned to grow to an ultimate size of 30 boats; this number depended on funding and perceived threats from the Soviet Union. As military funding and politics are precarious, only three boats were constructed.

The *Seawolf*-class subs are powered by the S6W Westinghouse pressurized water-cooled reactor that produces over 40,000 horsepower. A pair of General Electric steam turbines is used to drive a single shaft that drives a single multiblade, shrouded propeller, called a pump jet propulsor. This system is similar to the Mk 48 heavyweight torpedo. Estimated submerged speeds are over 35 knots. The first two of the *Seawolf* class were 353 feet in length, with a beam of 40 feet and a draft of 35 feet with a standard surface displacement of 7,460 tons and 9,138 tons submerged. The *Jimmy Carter* was designed as a special project multimission submarine and is 453 feet in length due to the 100-foot plug that was installed. The additional 100 feet is utilized to accommodate electronic equipment, Advanced SEAL Delivery Systems, and accommodations for covert action personnel. The *Jimmy Carter* was commissioned on 19 February 2005, with the former president in attendance.

The more expensive a submarine becomes, the more important it is to provide it with the most advanced defensive and offensive devices available. The *Seawolf* class was fitted with the BQQ-5 sonar suite in the bow. Three towed arrays were provided: two launched from fairings located one per side below the horizontal dive planes in anhedral fairings, and one that was carried in a launch and recovery tube located on the starboard outer side upper hull area. The TB-16 and TB-23 towed array is streamed behind the submarine to cover that area with sonar. The hull sides have six conformal wide aperture arrays, three per side. With these three types of sonar arrays, the *Seawolf* class has 360 degrees of sonar coverage. An advanced Mk 117 fire control system can handle all of the missile and torpedo launchings.

The *Seawolf* is equipped with eight of the 30-inch torpedo tubes, four per side located just aft of the bow. These tubes are equipped to launch the Mk 48 ADCAP (Advanced Capacity) heavyweight torpedo, and the Mk 50 high-speed Sea Lance torpedo. The Tomahawk and Harpoon missile systems can also be launched through the tubes. No vertical tubes were fitted to the *Seawolf* class. Various types of mines can also be carried and launched. A total of 50 torpedoes or missiles can be carried or 100 mines, or various combinations of both. A full range of countermeasures, such as decoys, noisemakers, and various other devices to mask the actual location of the submarine, is carried.

The *Seawolf* class will remain as one of the most important classes in regards to the design and development of future U.S. Navy submarines; it is intended that they will remain in service for over 50 years.

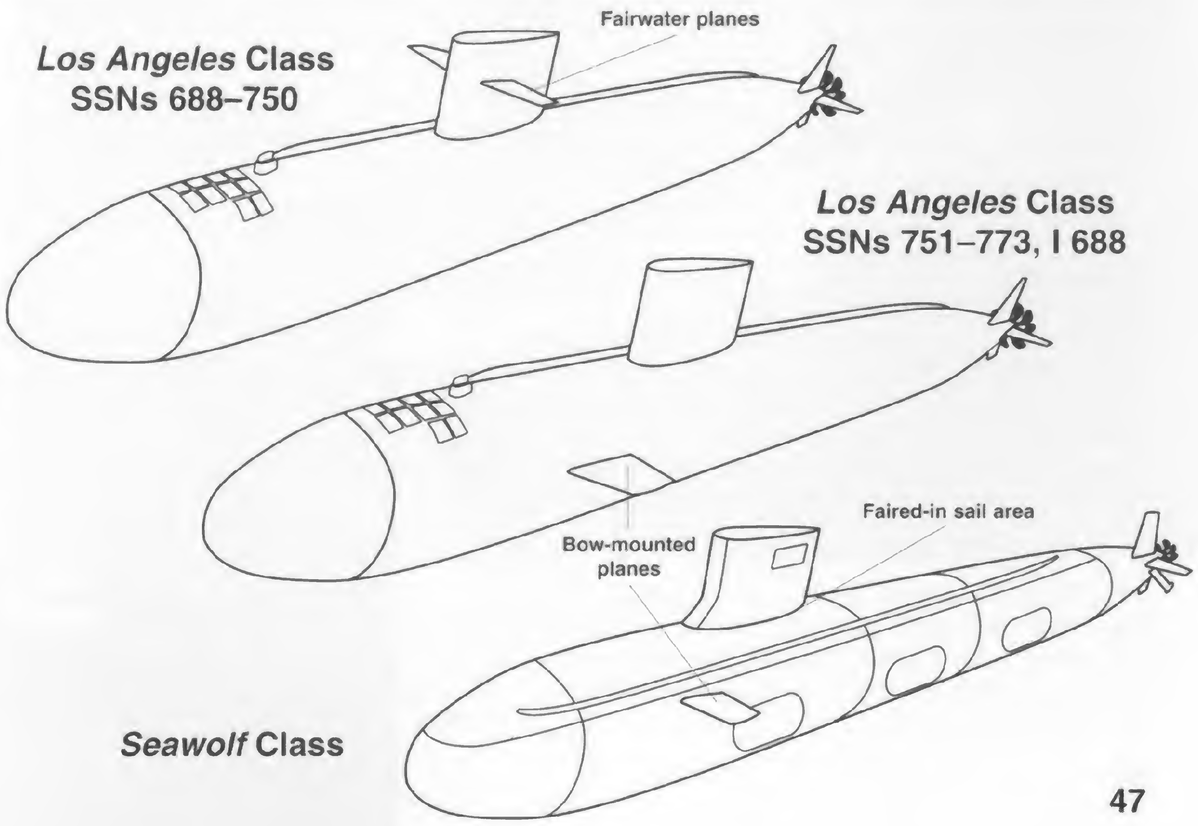
Connecticut (SSN 22) was the first U.S. Navy nuclear attack submarine named for a U.S. state. The U.S. flag flies from a gaff attached to the temporary safety rail erected for the sea watch. The attack periscope is painted a Light Green, while the extended navigation periscope and a communication mast are camouflaged. *(General Dynamics/Electric Boat Division)*

Seawolf (SSN 21) runs sea trials in the Atlantic in 1995 out of General Dynamics, Electric Boat Division. *Seawolf* has a faired in-sail and bow-mounted dive planes, and the hull is covered with rubberlike tiles that help to quiet the submarine and reduce hydrodynamic drag. The *Seawolf* was designed to test new technology for 21st century submarines. *(COMSUBLANT)*

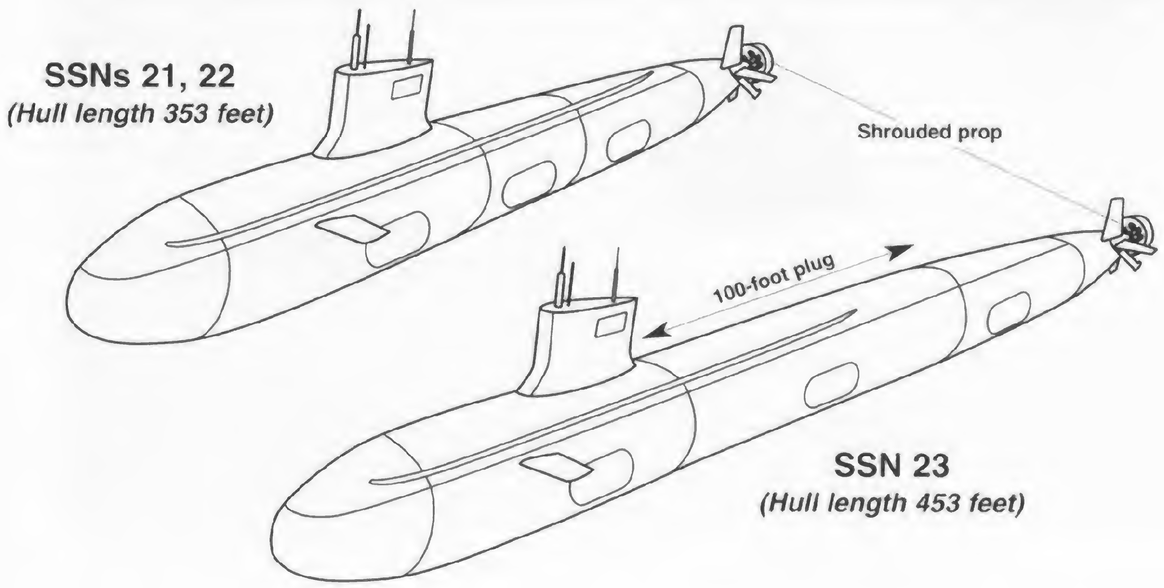
Seawolf on the surface with a communication mast and both attack and navigation periscopes extended. The mast sleeves are camouflaged in a Light and Dark Gray mottled pattern. *Seawolf* is armed with eight 30-inch torpedo tubes that can launch the Mk 48 ADCAP torpedo and the Tomahawk Land Attack Cruise Missile. *(COMSUBLANT)*

Connecticut (SSN 22), at the University of Washington Applied Physics Lab Ice Station (APLIS) 2003 Ice Camp, April 2003. *(COMSUBPAC)*

Dive Plane Development



Seawolf-Class Hull Development



Jimmy Carter (SSN 23) is the largest U.S. nuclear attack submarine ever built at 453 feet in length; she is just 6 feet longer than the *Triton* that was built 40 years earlier. Originally designed to be 353 feet in length, she was lengthened by inserting a 100-foot plug that accommodates electronic equipment, SEAL delivery vehicles, and other classified equipment. *(COMSUBLANT)*

Jimmy Carter (SSN 23), the largest U.S. nuclear attack submarine, moves out from the Electric Boat yard to conduct sea trials. The sea and deck watch has been posted, and watchstanders will be at their stations until the command "Rig the submarine for dive and secure all personnel" is given over the 1MC (intercom). The *Jimmy Carter* is being used as a "special project" submarine conducting covert operations and collecting data for future use. *(U.S. Navy)*

Virginia Class

The *Virginia* class employs all of the necessary tools to attack enemy submarine and surface targets, gather intelligence, insert covert action teams, and attack targets on land. All of these attributes required a completely new submarine design, and the *Virginia* class has these and many more. Originally called Centurion for the year 2000, the designation was changed to New Attack Submarine (NAS) and finally to NSSN (New Nuclear Submarine), one that could perform multiple missions.

The *Virginia* class now numbers six. *Virginia* (SSN 774) was commissioned in 2004, and *Texas* (SSN 775) and *Hawaii* (SSN 776) were commissioned in 2006. The *North Carolina* (SSN 777), *New Hampshire* (SSN 778), and *New Mexico* (SSN 779) have been named and will be in commission by 2008. Many of the features from the *Seawolf* class have been carried over to the *Virginia* class, such as the shrouded propulsor system, the multiple line towed array system, conformal array, faired-in sail, and multimission systems.

The *Virginia* class is 377 feet in length, with a beam of 34 feet and a draft of 32 feet. Submerged displacement is rated at 7,800 tons. An S9G General Electric reactor, which was designed to never need refueling, with over 50,000 SHP, powers the Improved Performance Machinery Phase III which was coupled to a single shaft that drives the multiblade shrouded propeller. This provides for submerged speeds in excess of 35 knots. Maximum diving depth was rated at 800 feet-plus. The hull was coated with a black rubberlike material that is not unlike that of a sea mammal.

The *Virginia* class is armed with four 21-inch torpedo tubes, two per side located between the control room and the Vertical Launch System (VLS). The VLS has 12 tubes for the Tomahawk land attack missile system. Unlike the torpedo tubes, they cannot be reloaded while at sea. The torpedo tubes also launch the Tomahawk as well as the Mk 48 and Mk 50 torpedoes and mines. For countermeasures, a single internal, reloadable launcher and 14 external launchers are employed.

For covert action, a single Advanced SEAL Delivery System (ASDS) can be hosted. The ASDS is a miniature submarine employed by SEAL and other covert action/intelligence gathering teams. A Dry Deck Shelter can be attached to the submarine's outer hull utilizing an escape trunk to enter/depart the submarine. A lockout trunk was also fitted aft of the sail for use by U.S. Navy divers. The *Virginia* class also has the capability to listen to signals from land and remotely control previously fired weapons, directing them to a designated target.

The *Virginia* class was the first to employ photonic masts that replaced the optic system that has been in use for over 100 years. Photonic masts eliminate the possibility of any light from within a submarine escaping out through the attack or navigation periscope. A further advantage is that the control room does not have to be placed under the periscopes, but can be placed basically anywhere in the ship, although the control room in the *Virginia* class was located under the sail, just one deck lower than usual. A *Seawolf*-type sail was fitted in the standard position. The sail had external storage areas for diver and other special-forces equipment.

The sonar array on the *Virginia* class is impressive and protects the submarine from all angles, from bow to stern. The integrated conformal array sonar sphere and chin sonar are in the bow. The sail contains a sonar array that is used to locate and map mines. On the side of the hull are lightweight wide aperture arrays, three per side, and at the stern are the TB-16 and TB-29 towed array systems, which give the *Virginia* class total sonar coverage. In addition, the wide aperture array can be used to map the sea floor and mine fields.

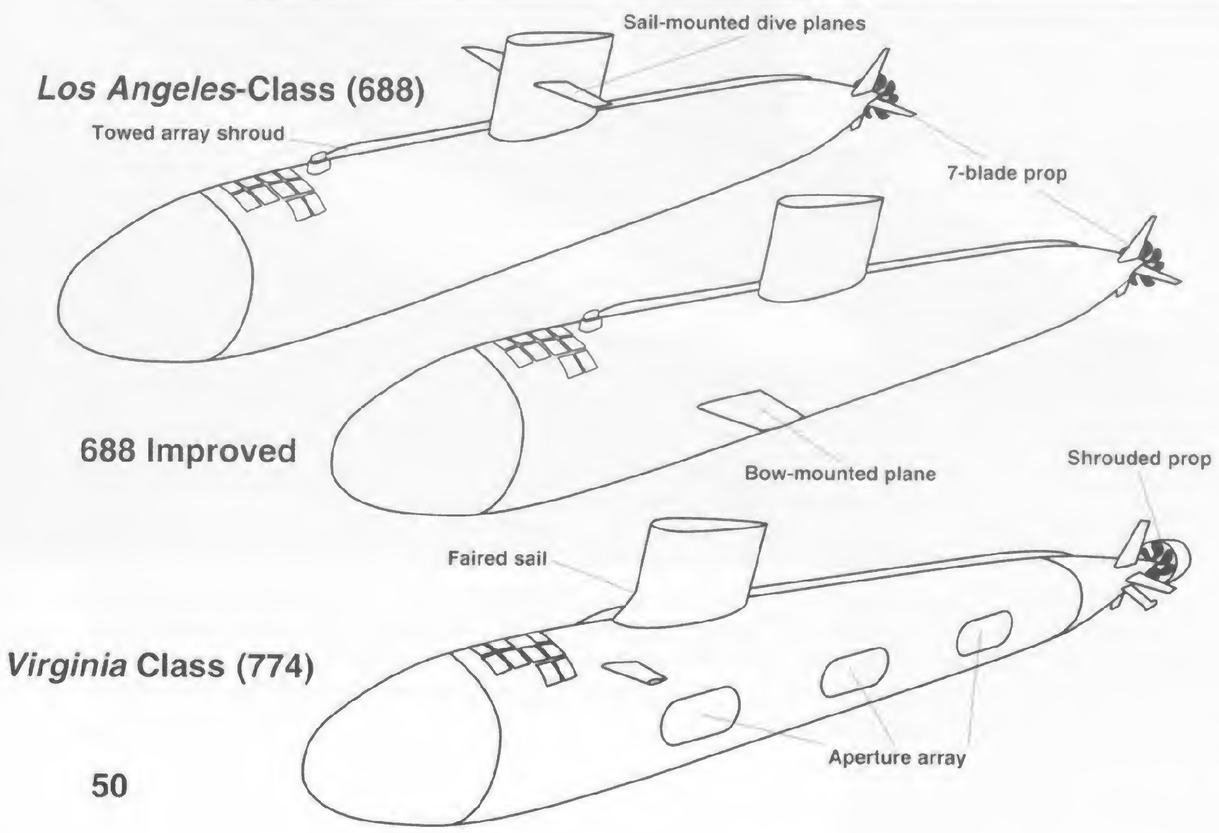
The *Virginia* class will be constructed by two yards. General Dynamics, Electric Boat division will construct the 774, 776, 778, and 779 boats, while the Northrop-Grumman Newport News Shipbuilding division will construct the 775 and 777 boats. As more of the *Los Angeles* class is decommissioned, more of the *Virginia* class will be authorized and constructed, assuring adequate submarines to protect U.S. interests.

Virginia (SSN 774) on precommissioning sea trials in the Atlantic in 2004. *Virginia* is the first in the class of attack submarines that will eventually replace the *Los Angeles* class. The attack and navigation periscope photonic masts are extended as well as the communication mast. The photonic masts are painted a Light Green. The snorkel is extended, indicating that the auxiliary diesel is being operated. *(COMSUBLANT)*

Texas (SSN 775) undergoes fitting out at a dry dock at Electric Boat in 2006 prior to her commissioning ceremonies on 9 September. The Texas flag has been placed on the sail-staging frame. *Texas* is the second of six *Virginia*-class attack submarines that have been constructed or are in the construction process. An Ocean Gray band has been painted on the side of the hull and the vertical rudder, a scheme not unlike that applied to *Nautilus* in the 1950s. *(COMSUBLANT)*

Texas proceeds out to sea for extended trials prior to her commissioning in 2006. A U.S. Coast Guard cutter has cleared a lane so the submarine could proceed unrestricted by traffic, and a Bell Model 206 helicopter is providing additional air coverage (not shown). *Texas* is 377 feet in length and displaces 7,800 tons submerged. She is capable of launching the Mk 48 ADCAP torpedo and the Tomahawk cruise missiles from her VLS system and torpedo tubes. *(COMSUBANT)*

Sail, Hull Development



The crew of *Texas* prepares the submarine to come into port at Galveston, Texas, for her commissioning ceremonies. All of the enlisted deck crew is wearing green shirts, and the obligatory life ring is propped against the sail in case of a man overboard event. The *Texas* flag has been erected on the sail safety rail, and a Jacob's ladder extends alongside the sail. A temporary navigation radar antenna has been installed at the top edge of the sail. Note that the escape trunk hatch swings to the side. *(COMSUBLANT)*

Conversions

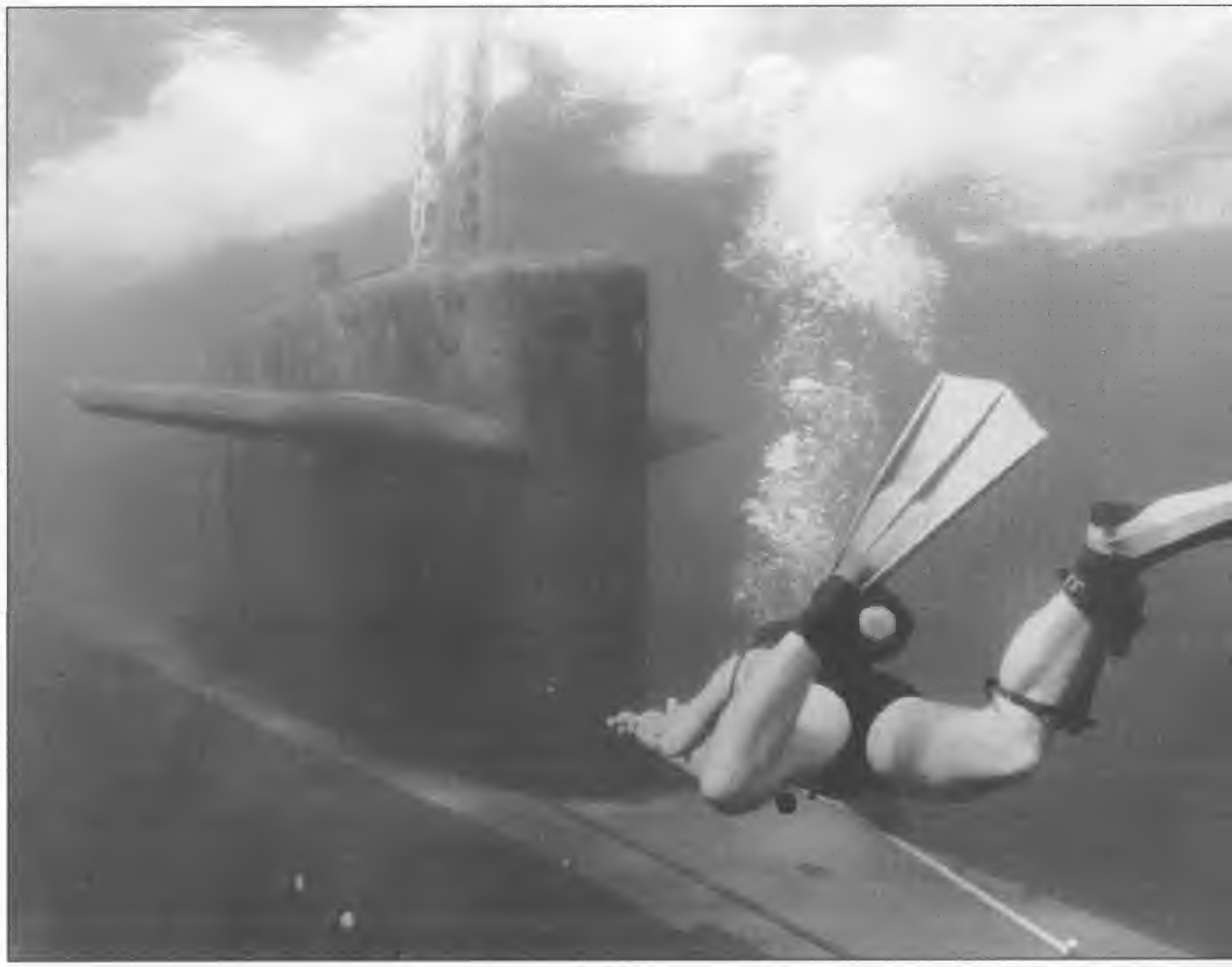
Beginning in 1980, the U.S. Navy undertook the conversion of three of the *George Washington* and five of the *Ethan Allen* classes of fleet ballistic missile (FBM) submarines by modifying the missile compartments into storage containers and portals for Dry Deck Shelters (DDSs), if so fitted. Further modifications included the removal of the entire missile launching electronics and mechanical devices that were relevant to their former status. Once converted, the submarines were used to transport SEAL and other covert action teams.

The converted submarines were reclassified as attack submarines (SSNs), as their former designator of SSBN no longer applied. There was still enough life in the old boats and the reactor to be useful for covert action and transport use. A pair of Dry Deck Shelters was installed on the *Sam Houston* (SSN 609) and the *John Marshall* (SSN 611). The Dry Deck shelters could be utilized to handle, launch, and recover SEAL Delivery Vehicles or for storage of equipment. By 1993, all of the eight converted transport boats had been decommissioned.

The *Kamehameha* (SSN 642) and *James K. Polk* (SSN 645), a pair of recently converted FBM submarines from the *Benjamin Franklin* class, replaced the eight earlier submarines in the transport role. The conversion to SSN was undertaken at Mare Island Naval Shipyard and Newport News Shipbuilding during 1992–1993. They were equipped to host a pair of Dry Deck Shelters, which were used to carry SEAL Delivery Vehicles or as a lockout chamber for swimmers. The *Kamehameha* was stationed at Pearl Harbor, Hawaii, and the *James K. Polk* at Norfolk, Virginia. By 2002, both had been decommissioned and struck from the Naval Register.

In 2004, four FBM submarines, *Ohio* (SSBN 726), *Michigan* (SSBN 727), *Florida* (SSBN 728), and *Georgia* (SSBN 729), were converted into a dual role — guided missile and transport submarine and redesignated as SSGNs. The conversions included the installation of rotary launchers in 22 of the 24 tubes for 154 Tomahawk land attack missiles, seven per tube. The remaining tubes would be used by covert action teams. Provisions were also made to carry Dual Advanced SEAL Delivery Systems (ASDS) just aft of the sail. Lockout chambers were also provided for U.S. Navy swimmers. This will enable the four converted submarines to operate in a littoral (close to shore) role.

(Above) John Marshall (SSN 611) was originally constructed as a fleet ballistic missile (FBM) submarine (SSBN) in the *Ethan Allen* class, but she was converted to a covert action/transport submarine status by converting the missile tube space to cargo storage and adding a pair of Dry Deck Shelters (DDSs) over the former missile compartment area. *John Marshall* was used for clandestine operations in the Kuwait/Iraq area during Operations Desert Shield/Desert Storm in the 1990–91 timeframe. The DDSs transport SEAL Swimmer Delivery Vehicles (SDVs). *(U.S. Navy)*



(Right) A U.S. Navy swimmer uses a reel device to return to *Sam Houston* (SSN 609), a former FBM submarine. The reel device, similar to a fishing reel, with a polypropylene line, is used by divers when working alongside a submarine. The diver will re-enter the submerged submarine utilizing the Dry Deck Shelters pressure chamber. *(U.S. Navy)*

More than 7,400 tons of Seawolf (SSN 21) makes an impression in the Atlantic during Bravo sea trials at Groton, Connecticut, 16 September 1996. (U.S. Navy)

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